

SCIENCE AND TECHNOLOGY

FOCUS

WHERE DOES
CONSCIOUSNESS
COME FROM?

WILL
ELECTRIC
CARS SAVE
OUR CITIES?

WHY THE
WORLD'S
RESOURCES
COULD LAST
FOREVER

+

THE
FUTURE OF
FIGHTING
CRIME

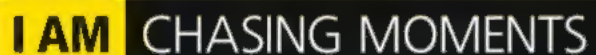
- AI detectives
- Predictive policing
- VR crime scenes

MATT RIDLEY ARGUES WHY OUR
PLANET'S FUTURE IS BRIGHTER
THAN YOU THINK

FIND OUT
HOW PAIN
WORKS

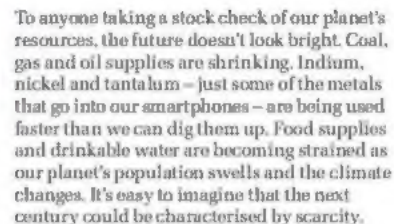
NEWLY DISCOVERED
MONSTERS
FROM THE DEEP

Nikon 100th anniversary



AUGUST 2017

WELCOME



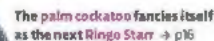
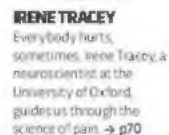
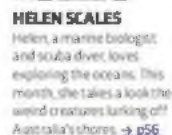
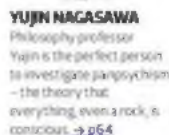
And that's without considering the ethical and ecological consequences of acquiring these precious resources. However, there is another way to look at this problem. On p36 Matt Ridley makes his case for a different future, one that's brighter than you might think.

Just one more thing... I'm a big crime fan. *Columbo's* more my flavour than *The Killing*; I love a great whodunnit. But the crime genre might be in trouble, as breakthroughs in the likes of genetics and AI are about to make solving crime a lot simpler. For instance, some cities are already working on systems that will help them predict crimes before they happen, much like earthquakes. And if someone does commit a crime, in the near future the police will probably be able to establish what the suspect looks like and what they've been up to from a few samples of blood and hair. There'll be no savvy-like detectives either, as all the real work will be done by an artificial intelligence that's studied every criminal case from the last decade. Even then, unless they teach it to gather all its suspects into a room before delivering a lengthy monologue revealing the culprit, I suspect crime writers are going to have to shake up the genre. I jest, but the point stands that the way we fight crime is going through a revolution right now, turn to p48 for more.

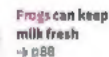
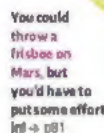
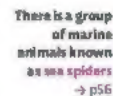
Daniel Bennett, Editor

Daniel Bennett

IN THIS ISSUE



WHAT WE FOUND OUT THIS MONTH



CONTACT US

Advertising
neil.lloyd@immediate.co.uk
0117 300 8278

✉ Letters for publication
neuro@sl.elsevier.com

Editorial enquiries
editorialenquiries@sciencefocus.com

0117 314 7389
Subscriptions

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INTERVIEW

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CONTENTS



27

REGULARS

6 Eye opener

Incredible images from around the world

11 Discoveries

All of the month's biggest science news. PLUS: Will electric cars save our cities?

25 Innovations

The coolest tech we've seen this month. PLUS: BMW i30d xDrive on test.

34 Reply

Your letters and emails.

77 Helen Czerski

This month, Helen munches scones while pondering the mysteries of light.

79 Q&A

Could you throw a frisbee on Mars? Do seagulls drink seawater? How does exercise reduce stress? These questions and more answered.

90 Out there

All the best science-y stuff to do this month.

96 Crossword

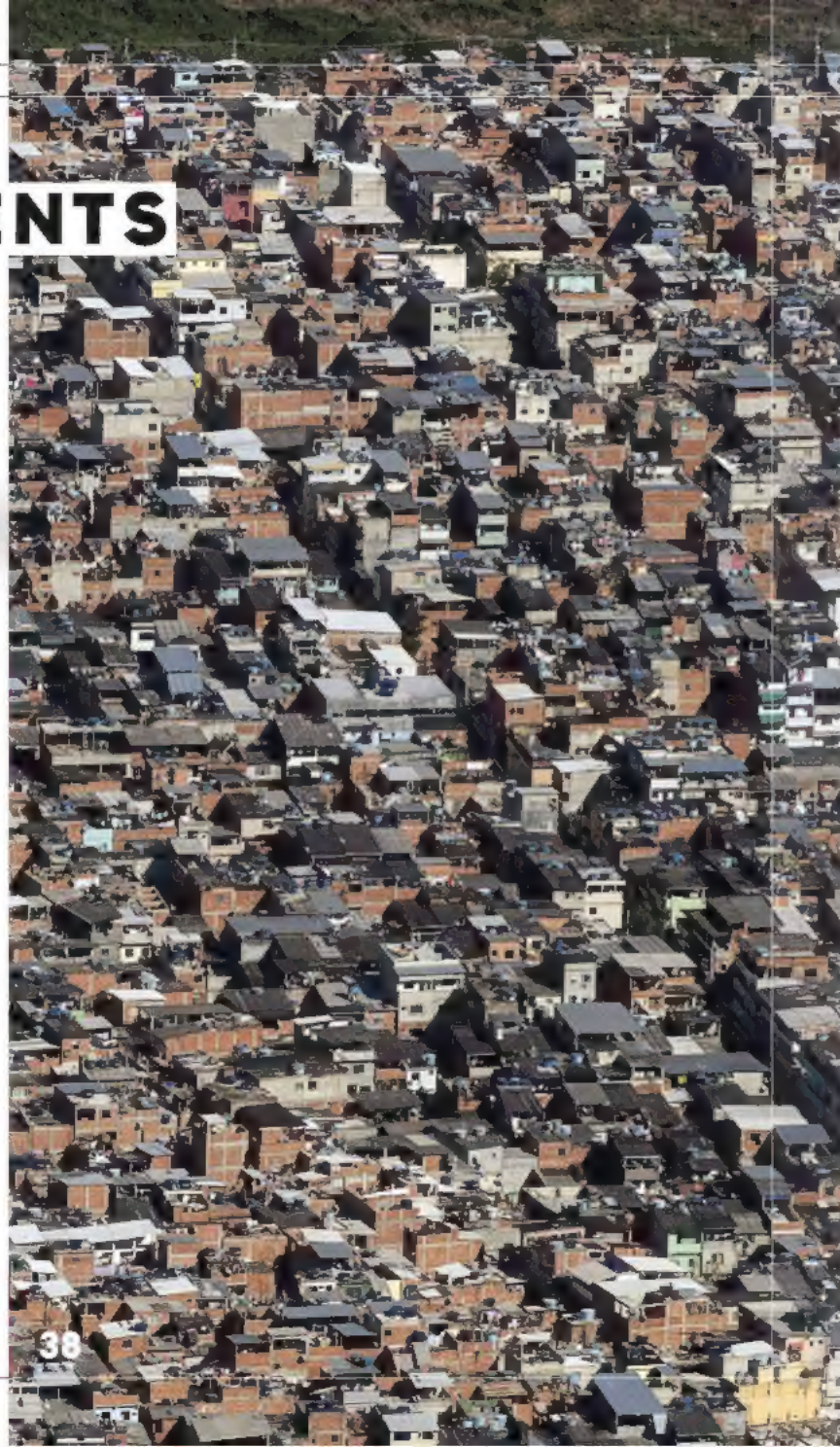
It's like a workout for your brain!

98 My life scientific

Helen Pitcher chats about Indiana Jones and destroying ancient artefacts with archaeologist Dr Brenna Hassett.

46 Subscribe

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FEATURES

Could the world's resources could last forever?

38 Tory peer Matt Ridley thinks that innovation will stop resources from running out.

The future of fighting crime

48 Revolutionary technology could give police new tools to stop criminals in their tracks.

Newly discovered monsters from the deep

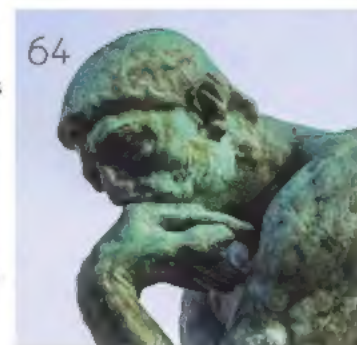
56 The 4V Investigator has been finding some creepy crabs in the ocean's inky depths.

Where does consciousness come from?

64 Could the weird theory of 'panpsychism' help explain consciousness?

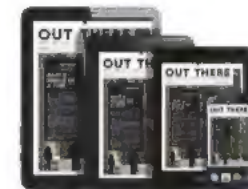
How pain works

70 Neuroscientist Irene Tracey outlines the biology behind pain. Still doesn't make us feel better about stubbing our toes, though.



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EYE OPENER

Slippery customer

NAMIB DESERT,
NAMIBIA

If you find yourself wandering through the vast deserts of Namibia, watch where you put your feet! The Peringuey adder, also known as *Bitis peringueyi*, spends much of its time buried under the sand. As an ambush predator, the snake needs to remain unseen, and the sand provides the perfect camouflage.

Dr Brian Crother from Southeastern Louisiana University says: "The desert adder burrows into the sand, leaving its eyes, that sit on top of his head, and its black-tipped tail exposed. The black tail tip is gently waved about and used as a lure to bring lizards [its prey] within striking distance."

As a desert-dweller, the snake has a number of adaptations to survive in the harsh environment. First, it can travel using a form of locomotion called 'sidewinding', where just two points of its body are in contact with the sand at a time. This allows it to move quickly across loose terrain, and reduces contact with the hot sand. Second, water from morning fog condenses on its body, which it then drinks.

PHOTO: ALAMY





EYE OPENER

Swell snap

HAWAII,
USA

Photographer Sash Fitzsimmons claims he risked his life to take this incredible image. And physicist and oceanographer Dr Helen Czerski agrees that it's a dangerous business.

"The energy of a barrel wave like this one ultimately comes from the wind pushing the ocean surface into ripples and then up into bigger and bigger waves," she says. "As the water gets shallower, that energy is concentrated and the waves steepen until they break in these beautiful long barrels. One cubic metre of water weighs a tonne, so the rapid movement of this much water represents a huge amount of kinetic energy. Both the surfer and the photographers need superb judgment – and a bit of luck – to stay safe."

To take the picture, Fitzsimmons used a GoPro camera with a fisheye lens. It was fitted with a dome to push water away from the camera, allowing him to capture the action above and below the surface.

PHOTO: CATERS NEWS

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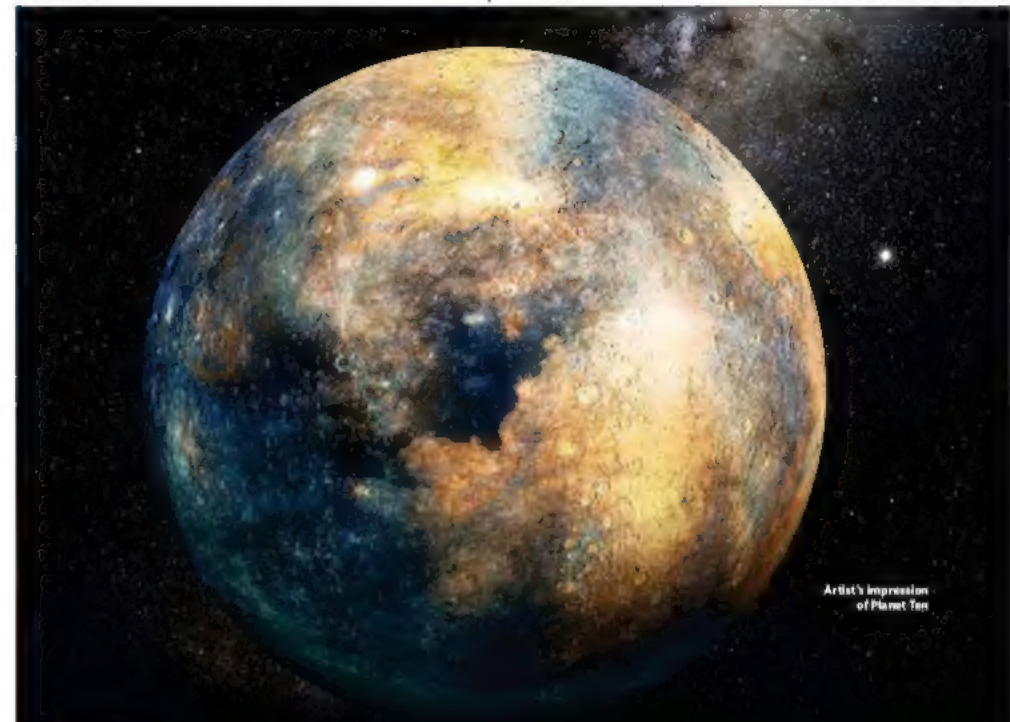
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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

AUGUST 2017

EDITED BY JASON GOODYER



Artist's impression
of Planet Ten

SPACE

IS THERE A TENTH PLANET?

Astronomers in the US have inferred the existence of an unknown 'planetary mass object' affecting the movements of space rocks in a distant asteroid belt

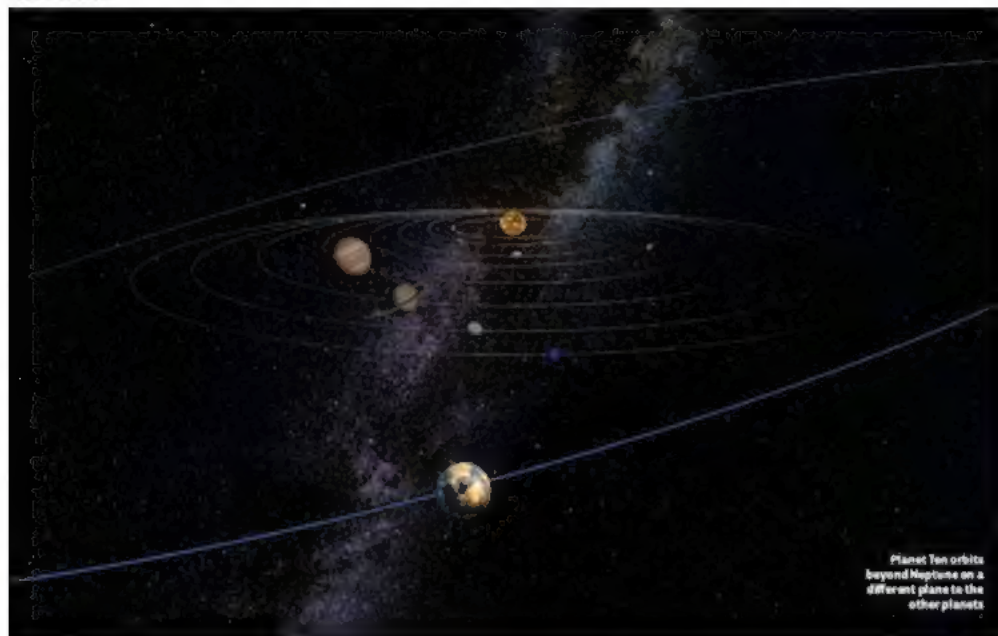
It seems the Solar System may be a little more crowded than we thought: a planet around the size of Mars could be hidden among its outer fringes.

A team from the University of Arizona has discovered a mysterious mass, dubbed Planet Ten, that appears to be tugging at the orbits of a population of space rocks known as the Kuiper Belt in the icy outskirts of the Solar System. The Kuiper Belt lies beyond the orbit of Neptune and

extends to a few hundred Astronomical Units (AU) with one AU representing the distance between Earth and the Sun.

The Earth and the other major planets all orbit the Sun in roughly the same plane. However, Kuiper Belt Objects (KBOs) are far enough away from the gravitational attraction of the gas giants to be tilted away from this plane, and are affected by interactions with one another.

PHOTO: NASA/JPL



Planet Ten orbits beyond Neptune on a different plane to the other planets

This angle, known as the inclination, can be calculated. If the observed angle differs from the one calculated, then it's possible that the smaller KBOs are being pulled out of line by something more massive – potentially an undiscovered planet. This method is how the existence of the so-called Planet Nine was predicted last year.

After analysing more than 600 objects in the Kuiper Belt, the researchers found a discrepancy of 8° at around 50 AU away from the Sun.

"The most likely explanation for our results is that there is some unseen mass," said researcher Kai Volk. "According to our calculations, something as massive as Mars would be needed to cause the warp that we measured."

The researchers say we may not have directly observed the planet because we haven't yet searched the entire sky for distant objects in the Solar System. However, a chance may come in 2020 when the Large Synoptic Survey Telescope (LSST) is completed.

"We expect LSST to bring the number of observed KBOs from currently about 2,000 to 40,000," researcher Renu Malhotra said. "There are a lot more KBOs out there – we just have not seen them yet. Some of them are too far and dim even for LSST to spot, but because the telescope will cover the sky much more comprehensively than current surveys, it should be able to detect this object, if it's out there."

**"THE MOST
LIKELY
EXPLANATION
FOR OUR
RESULTS IS
THAT THERE
IS SOME
UNSEEN MASS"**

EXPERT COMMENT

Colin Stuart

Astronomer and author

"All eyes are on the outer Solar System right now. First, astronomers found tantalising clues of a ninth planet beyond the orbit of Neptune. But now there might be a tenth, too."

We shouldn't really be surprised. The early Solar System was a much more chaotic place than the largely serene environment of today. Another planet is thought to have whacked into the Earth to form the Moon, for example. What's more, computer models of Solar System formation work better if there were more than four gas planets to begin with. Today's gas planets were the gravitational victors in the Solar System's childhood squabbles. Planets Nine and Ten, should they be confirmed, were likely bullied into far-flung orbits.

But why is it taking until now to find them? After all, we've found more than 4,000 planets beyond our Solar System. We don't spot those exoplanets directly – we look for changes in the light from their host stars to infer their presence. For us to see a distant planet in our own Solar System, light has to trek from the Sun all the way out there and back to the Earth, fading all the while. So they're on the edge of what we can see with current telescopes. With the potential Planet Ten, the task is even trickier due to its likely position close to the bright Milky Way.

Should the planets be found, more than a decade since Pluto was knocked off its planetary perch, the textbooks will need ripping up again."

PHOTOS: HEATHER DORRILL; NASA/ESA/CATED; WIKIMEDIA/JASON MAYER

MATHS

COMPUTATIONAL ORIGAMI TAKES A BIG LEAP FORWARD

An MIT professor of computer science and an assistant professor in civil engineering at the University of Tokyo have joined forces to come up with a better way of... making paper rabbits. Or rather, they have created an algorithm that enables the creation of any 3D shape from a single sheet of a given material.

MIT's Prof Erik Demaine has previous experience in this area: his 1999 PhD thesis described the same thing. The difference, though, is that his previous algorithm essentially involved taking a long, thin strip of paper or other material and winding it into the desired shape. This tends to leave you with lots of seams in the finished 3D shape, and is inefficient in terms of the amount of paper (or other material) required. The new algorithm, on the other hand, preserves the

boundaries of the original sheet of paper, and minimises the number of seams. "It's a totally different strategy for thinking about how to make a polyhedron," said Demaine.

If you've ever unfolded a paper cup from the water cooler, and ended up with a circular piece of paper, that's the perfect example of how the new algorithm works – the outer edge of the circle ends up as the rim of the cup. Demaine's old method, however, would have created a non-watertight cup shape by winding a thin strip of paper into a coil.

The technique could have practical applications in manufacturing, particularly in areas such as designing and building spacecraft, where materials efficiency is of paramount importance.



The new origami algorithm can make any shape from a single sheet of material

IN NUMBERS

**1,203
KM**

The distance Chinese researchers were able to successfully preserve quantum entanglement in a pair of photons – that's a new record.

**66
MILLION**

The numbers of trees planted by 15 million volunteers in Madhya Pradesh, India in 12 hours in an attempt to combat climate change.

**5,100
SQUARE KM**

The size of a giant iceberg that broke off an Antarctic ice shelf in the Weddell Sea. That's an area almost four times the size of greater London.



Volvo claims that by 2019 all its new vehicles will be electric or hybrid, like this XC90 model

PHOTO: NEWSPHOTO.COM

CAN ELECTRIC CARS SAVE OUR CITIES?

As Volvo announces plans to go all-electric by 2019, transport expert Ian Walker weighs up the environmental pros and cons

Volvo is the first major car company to announce that all its cars will soon have electric motors. None of its new models will rely solely on internal combustion after 2019, and other manufacturers are presumably not far behind. So what does this mean for the environment, and for our congested cities? Are electric cars really as eco-friendly as we're led to believe?

There is one area where electrification clearly brings an advantage, and that is exhaust emissions. Fumes from vehicles are implicated in around 40,000 premature UK deaths every year, with around 9,000 in London alone. Diesel fumes are a major issue here, although petrol is hardly benign. Vehicle emissions cause a host of unpleasant conditions, including cancer, heart disease, diabetes and Alzheimer's. Shifting to electric vehicles has the potential to change this dramatically, especially in urban areas.

There is also the possibility that electric cars, in the long term, might introduce a virtuous cycle of energy efficiency. Electric motors are not as heavy as their oil-powered ancestors, which means the overall vehicle can be lighter. In a country where most vehicles have become lighter, the damage from impacts is reduced. This means cars need less protective armour, which makes them even lighter, so they need even less energy to get around, which further reduces their damage, and so on...

Finally, there is the possibility of reduced carbon emissions, although this one is a bit less clear-cut. The carbon cost of electricity entirely depends on how it's generated. I'm writing this on an overcast, still day, and right now 49.4 per cent of UK electricity is from burning gas. Charging a car now would be far less green than charging it when it's sunny or windy. The greenness of electric vehicles, then, depends either on people's willingness to hold off charging them until conditions are good (which, based on some of our research at the University of Bath, looks unlikely) or a breakthrough in battery technology that allows energy to be stored efficiently from good days to bad days.



Head of Volvo
Håkan Samuelsson at the announcement

**"GOING ELECTRIC
WOULD DO
NOTHING TO REDUCE
CONGESTION"**

Given their potential advantages – and the lack of urban pollution is one that's particularly appealing – it would be easy to become highly enthusiastic about electric cars. Many people already have. Governments might even be tempted to subsidise them to encourage a rapid uptake. But before we rush headlong into an electric future, it's important to consider any possible downsides too.

The main issue is that cars – both by their intrinsic design and by the way we use them – are associated with a broad range of problems that, at best, will be untouched by taking out a combustion engine and replacing it with an electric motor. Going electric would do nothing to reduce congestion – indeed, it could plausibly make it worse if pollutionless driving starts to feel 'guilt-free'. Electrification also fails to address the issue of where we store cars when they're not being used – and when you think about it, that's almost all the time.

There's also a host of issues that electrification, at best, addresses to such a marginal degree that it's hardly worth the bother. Take noise pollution. This is a far bigger public health problem than you would believe, contributing to conditions like hypertension, sleep disorders, and behavioural problems in children. But above even modest speeds, the noise from cars is mostly from the tyres, not the engine. Research we've carried out at Bath, with colleagues from Trinity College Dublin, showed that even if vehicles went 100 per cent electric overnight, the noise issue would be only very slightly reduced. Hardly a ringing endorsement.

But perhaps the greatest public health issue of our age is one that electrification completely fails to address: physical inactivity. The way we build and run our towns and cities means that it's easy, and socially acceptable, to drive short distances. At least a quarter of English car journeys are under two miles, usually taking up precious road space by carrying around several empty seats. These are journeys that in most cases would be quicker, cheaper and a great deal healthier and less congesting if walked or cycled. The guilt-free nature of electric cars could even make this slightly worse.

There are certainly advantages to a change like Volvo's, particularly when it comes to reducing urban pollution. But all we are being offered at the moment is the chance to replace cars' engines, not to look at the way we use cars in society. This means that we fail to work towards towns and cities that are truly healthier, safer and more welcoming, and we fail to free rural communities from their car dependence. There's a sense in which electric cars are old milk in new bottles. Really we should be asking far more fundamental questions about how and why we travel rather than just what sort of engines our cars have.

Drian Walker is a psychologist at the University of Bath who specialises in traffic safety, transport choices and energy consumption.



Dave the cockatoo had been practising for his Counting Crows audition

ZOOLOGY

COCKATOOS GOT RHYTHM

Birds might generally be better known for their singing, but new research carried out by Prof Rob Heinsohn from the Australian National University (ANU) has proved they can also be a dab hand on the drums.

The palm cockatoo – also known as the goliath or great black cockatoo – is native to New Guinea and to Australia's Cape York Peninsula, an area of untamed wilderness in the far north of Queensland. It was here that Heinsohn's team were, for the first time, able to capture enough film of the reclusive species' drumming behaviour, which had previously been reported anecdotally, for serious study. The footage was obtained as part of a wider study into the bird's conservation needs.

Heinsohn and his team at the ANU Fenner

School of Environment and Society analysed seven years' worth of footage of 18 male cockatoos, and found that all 18 of the birds drummed regularly.

"The large smoky-grey parrots fashion thick sticks from branches, grip them with their feet and bang them on trunks and tree hollows, all the while displaying to females," said Heinsohn. "The icing on the cake is that the taps are almost perfectly spaced over very long sequences, just like a human drummer would do."

What's more, each cockatoo was found to have its own signature style, with some drumming faster or slower, and others introducing distinctive flourishes to the otherwise regular beat. It's thought that this enables other cockatoos to determine who is drumming where.

PHOTOS: LEONIEK; CHRISTINE DANIEL/AMY ILLUSTRATION: DANIEL BRYANT

SPACE

JUPITER'S GREAT RED SPOT CAPTURED IN UNPRECEDENTED DETAIL

NASA's Juno probe has delivered the goods yet again. This time, with photos of Jupiter's iconic Great Red Spot that were taken on 10 July.

The stunning images were pieced together by citizen scientists using raw data taken from the JunoCam as the probe passed just 3,500km above the planet's cloud tops – the closest any human-made object has come to the storm.

"I have been following the Juno mission since it launched," said citizen scientist Jason Major, who produced one of the images. "It is always exciting to see these new raw images of Jupiter as they arrive. But it is even more thrilling to take the raw images and turn them into something that people can appreciate. That is what I live for."

Measuring 16,350km across, Jupiter's Great Red Spot is a vast,

raging storm 1.3 times as wide as Earth. It has been under observation since 1830 and is believed to have existed for more than 350 years.

Early analysis of data taken by Juno portrays Jupiter as a highly turbulent world, with a complex interior structure, energetic polar auroras, and huge polar cyclones.

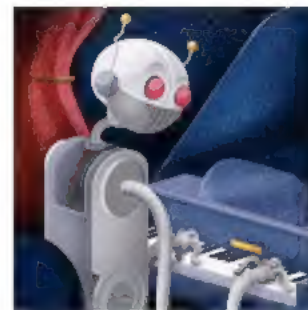
"For hundreds of years scientists have been observing, wondering and theorising about Jupiter's Great Red Spot," said Juno's principal investigator Scott Bolton. "Now we have the best pictures ever of this iconic storm. It will take us some time to analyse all the data from not only JunoCam, but Juno's eight science instruments, to shed some new light on the past, present and future of the Great Red Spot."

Juno's next close flyby of Jupiter will occur on 1 September.



Enhanced colour image of Jupiter's Great Red Spot

THEY DID WHAT?!



ROBOT TAUGHT TO COMPOSE MUSIC

What did they do?

Computer scientists at Georgia Institute of Technology in the US have taught a robot to compose its own musical pieces, and then play them on the marimba – an instrument similar to a xylophone.

How did they do that?

The robot – nicknamed "Shimon" – was fed nearly 5,000 complete compositions, ranging from pop songs to classical pieces, and over two million smaller fragments such as riffs, solos and codas. Using deep learning techniques, its AI system then analysed the material and devised its own set of rules for composition. Using these rules, it then "wrote" and played recognisably musical creations of its own.

Why did they do that?

Project leader Mason Bretan is interested in exploring the possibilities of AI and computer learning in music composition. Maybe the first robot masterpiece is just around the corner.

NEUROSCIENCE

"Video games are continually challenging our skills, making the brain perform at 100 per cent of its capacity"

Do video games change the brain? Different studies have reached different conclusions, so Marc Palaus, a neuroscientist at Spain's Universitat Oberta de Catalunya, reviewed the research

ABOVE Do computer games make you more violent, or just more clever?

Do video games affect behaviour?

Video games are likely able to affect the way we behave in a number of ways. For instance, there's concern about whether violence in games makes young people more violent. It's not uncommon for news outlets to blame games every time a crime happens, but how true is that claim?

This is controversial even within the scientific community. Yes, exposure to violence seems to affect the brain, but studies have also found that we're good at distinguishing between real and virtual violence, and aggressive behaviour is better explained by other, mainly socio-economic factors. Numerous studies about the effects of games on the brain had been published, but all that information had not been put together until now.

How did you review the research?

We gathered all scientific articles to date and compared results. In total, we found 116 experiments, the first from the 1980s. Many compared regular video game players with people who had never played; others trained people in a game for several weeks and studied its effects. Changes in the brain were measured using magnetic resonance imaging (MRI) or

electroencephalography (EEG), which detect whether brain regions increase or reduce in size, and how it affects their activity.

Are games bad for the brain?

The clearest negative impact is the risk of abuse and addiction by people with predisposing personality traits. Video games can affect the reward circuits, containing the pleasure centres of the brain. This in turn could affect other brain functions in the frontal lobe, possibly affecting the capacity for planning, inhibiting distractions and mental problem-solving.

Games that heavily rely on online multiplayer modes are the most associated with addiction, due to social interactions being more rewarding than just playing against the computer.

Can games be good for you?

Since video games usually display increasing levels of difficulty, they are continually challenging our skills, making the brain perform at 100 per cent of its capacity, resulting in effective cognitive training.

Various mental functions seem to benefit from this effect. Of these, attention is the most

studied, and its enhancement allows us to better process objects in our visual field, selecting those which are relevant and ignoring the rest.

Attention improvements have a positive effect on 'executive functions', mental processes involved in controlling behaviour, solving problems and facilitating learning – functions that are closely linked to intelligence. Visuospatial skills – our capacity to process visual and spatial information – are also improved.

Can games be useful?

Video games contribute to the correct functioning of our brain, and can even improve it. So we have to get rid of our prejudices and accept them as valid entertainment. This also opens the door to using games as a form of training in clinical settings, especially for those with cognitive deficits.

BELOW In some hospitals, video games are already used to help rehabilitate stroke patients



PHOTOS: SHUTTERSTOCK/GETTY ILLUSTRATION: DAN BRIGGS



THE FORGETFUL

Do you often find it difficult to remember what you had for dinner last night? You might be a genius. Canadian researchers have found that jettisoning unimportant memories helps us to focus on the most important information.

COFFEE DRINKERS

Make mine a quadruple espresso! People who drink two to three cups of coffee a day are 18 per cent less likely to die from heart disease, cancer, stroke, diabetes and kidney disease, a team at the University of California has found.

GOOD MONTH

BAD MONTH

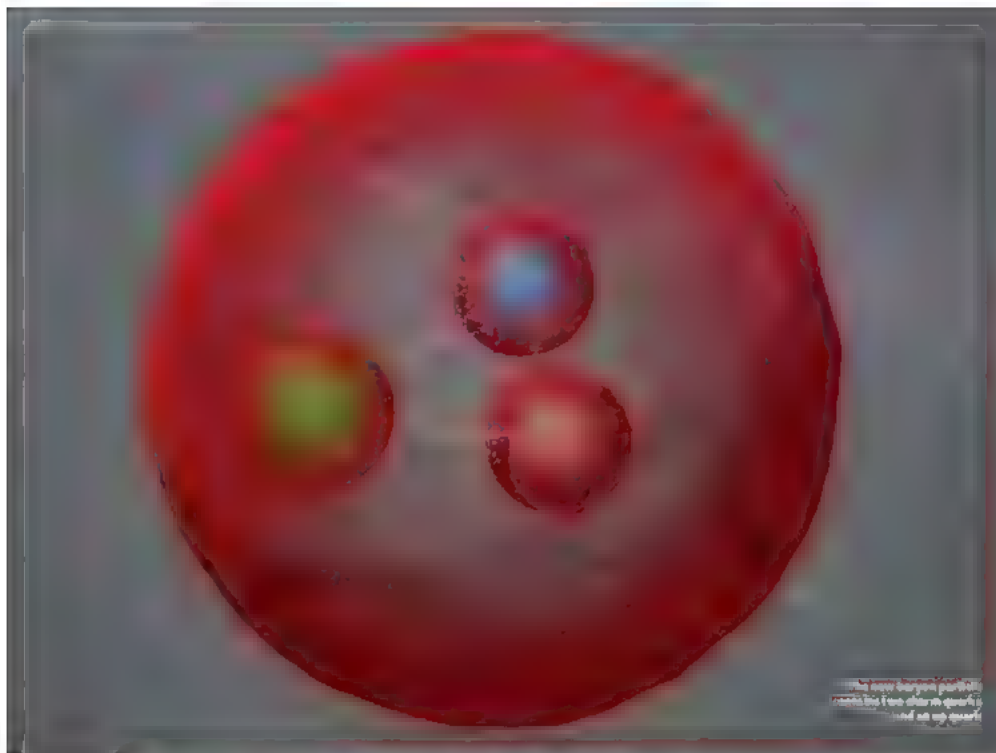
SMARTPHONE ADDICTS

If you break out in a sweat when your smartphone's out of reach, it may be time to rethink your habits. A University of Texas team has found that having a smart device in sight reduces our ability to focus and perform tasks.

TEENAGERS

So much for the vitality of youth! Researchers at the University of Baltimore have found the activity levels of the average 19-year-old are the same as those of people in their sixties.





PHYSICS

NEW SUBATOMIC PARTICLE DISCOVERED AT CERN

What a charmer! Scientists working at the Large Hadron Collider have found a new kind of subatomic particle. The particle is a baryon (a particle consisting of three quarks) named Ξ_{cc}^{++} and is part of a family of 'doubly charmed baryons' whose existence had previously been predicted by the Standard Model of particle physics, but never observed. The research, led by University of Glasgow physicist Dr Patrick Spradlin, was carried out at the Large Hadron Collider's LHCb detector. All the matter we see around us is comprised of protons and neutrons, which are baryons made of the lighter up and down quarks. Baryons that include the heavier charm, top, strange or beauty quarks decay almost instantly into protons and neutrons, making them hard to detect.

Many baryons have been observed with one heavy quark but Ξ_{cc}^{++} is the first one that's ever

"FINDING A NEW HEAVY-QUARK BARYON IS OF GREAT INTEREST"

been seen with two heavy quarks—in this case two charm quarks.

The properties of the newly discovered Ξ_{cc}^{++} baryon shed light on a longstanding puzzle surrounding the experimental status of baryons containing two charm quarks, opening an exciting new branch of investigation for LHCb, said Spradlin. The new baryon is around 3.5 times heavier than a proton or neutron, and has an electric charge twice that of a proton. The Glasgow team discovered over 300 Ξ_{cc}^{++} particles lurking in last year's LHCb data.

"Finding a new heavy-quark baryon is of great interest as it will provide a unique tool to further probe quantum chromodynamics, the theory that describes the strong interaction, one of the four fundamental forces," said researcher Giovanni Passaleva.

PHOTO: CERN/Getty

THINGS WE LEARNED THIS MONTH

MARS IS COVERED WITH TOXIC COMPOUNDS

The surface of the Red Planet is teeming with chemicals that could wipe out living organisms, say researchers from Edinburgh University. This finding greatly reduces the chances of finding life on Mars.

OUR BRAINS BENEFIT FROM PHYSICAL EXERCISE

Working out can be just as beneficial for our brains as our bodies. A team at the University of Arizona has found that taking exercise leads to improvements in brain structure and function—an effect thought to be linked to our evolution from sedentary apes to active hunter-gatherers.

CHILDREN WHO SLEEP LESS COULD AGE FASTER

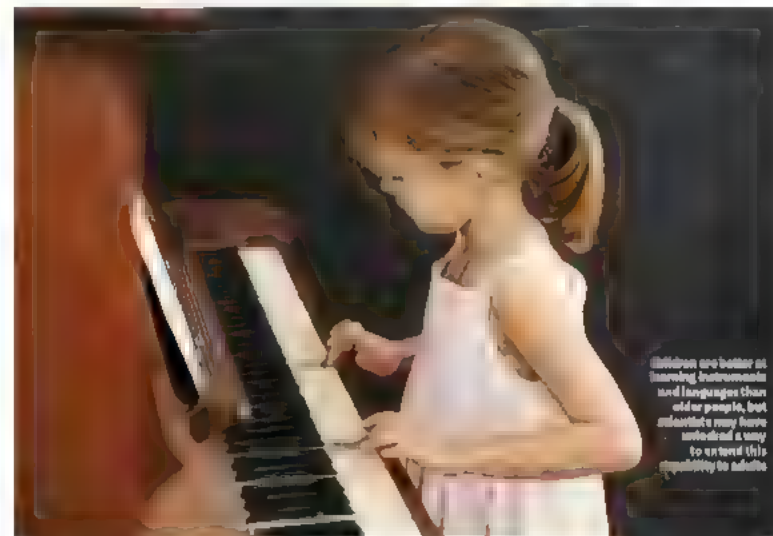
Telomeres are structures at the end of our chromosomes that shorten with age. In nine-year-old children who miss out on sleep, they are significantly shorter than in kids who sleep more, a study at Princeton University has found.

EARTH IS ON THE BRINK OF MASS EXTINCTION

Over the last century, Earth has undergone a decline in mammal populations akin to biological annihilation, according to Mexican researchers. This is due to human overconsumption and overpopulation, they say.

NEUROSCIENCE

'LEARNING WINDOW' FOR LANGUAGES AND MUSIC EXTENDED USING SINGLE BRAIN CHEMICAL



Children are better at learning instruments and languages than older people, but scientists may have unveiled a way to extend this opportunity to adults.

If you want your child to become fluent in foreign languages, or grow up to be a concert pianist, then the advice has always been to start them as early as possible. There's a sound scientific reason for this: children have a much greater capability for auditory learning than adults. But now, in news that will delight pushy parents everywhere, researchers at St Jude's Children's Research Hospital in Memphis, Tennessee have managed to extend this 'learning window' into early adulthood, albeit only in mice so far.

The researchers used several different techniques to either reduce the brain's supply of the neuromodulator adenosine, or block the A1 receptor that is vital to its function. Adenosine inhibits the release of the neurotransmitter glutamate, which is used by the auditory

thalamus and the auditory cortex, the areas of the brain that process sound. With adenosine production and activity suppressed, the auditory thalamus and cortex had more glutamate to work with. As a result, the adult mice with lower levels of adenosine exhibited a greater ability to differentiate between tones than adult mice in the control group.

"These results offer a promising strategy to extend the same window in humans to acquire language or music ability, possibly by developing drugs that selectively block adenosine activity," said research lead Dr Stanislav Zakharenko.

Be warned though: Adenosine is also involved with sleep and suppressing arousal. So if your virtuoso violinist grows up to be an insomniac sex maniac, don't come crying to us.



PREDICTING THE UNPREDICTABLE

It's the end of the world as we know it, again. And I feel fine...

Ten years ago this month, an event took place in Paris which signalled the start of EOTWAWKI. No, it's not a Maori festival, it's something much less fun. The End Of The World As We Know It.

In August 2007, a French investment bank told some of its clients they couldn't get access to £1bn of their own money. While undoubtedly bad news for those involved, it didn't seem like a huge story for the rest of us. But what happened on that Thursday afternoon is now widely seen as the start of the Global Financial Crisis.

Over the following year, trillions of pounds of wealth evaporated, global financial institutions went bust and the world's economy teetered on the brink. The cause was the discovery that vast financial bets had been made by banks about the health of US housing market. Bets that were complex, interconnected and frankly stupid. And when they started to go wrong, the consequences went global – and changed the world forever.

Now there's talk of EOTWAWKI coming around again. This time, it's soaring consumer debt that's prompting concern. From car loans to credit cards, levels of debt are soaring again.

So, is The End nigh – again? Unlikely. Sure, there are lots of pundits predicting it, but then there always are. What they've missed is the fact that we really did experience EOTWAWKI in 2007. No, the end of the world as in Armageddon, but literally the end of the world as we used to know it.

Back then, many experts thought it was possible to make predictions about, say, the US housing market and make bets – and money – accordingly. Some even thought they could tell when the economy was in trouble. Not any more. Now financial regulators and central banks are far more sceptical about economic forecasts and the reliability of financial models. Most have come to accept that another crisis

"WE MAY BE WITNESSING A REVOLUTION IN THE WAY HUMANITY DEALS WITH THE INEVITABLE UNCERTAINTIES OF LIFE IN A COMPLEX WORLD"



is pretty much certain, but that it is also pretty much certain that no one can say with any degree of confidence when it will strike.

So, regulators now insist that banks keep a greater chunk of their wealth sitting in their vaults for when the inevitable happens. They also have to undergo regular 'stress tests' which simulate the impact of severe downturns. A close eye is also kept on smart-aleck bets of the kind that caused mayhem a decade ago.

None of this is guaranteed to stop a repeat of 2007, but it does reduce the risk. And when it comes to dealing with uncertainty, that's as good as it gets. It's an attitude that's gaining traction elsewhere – and not before time. After spending decades and billions trying to predict natural disasters like droughts, storms and earthquakes, governments are increasingly focusing on reducing the high-risk areas and taking better care of them.

Atmospheric global warming are also changing. Despite decades of effort, it's clear that climate models still struggle with the complexity of predicting the future in detail. What is clear is that we can't carry on the way we are and must act now to reduce the risk of disaster. That's a truth that is recognised in the much-maligned Paris climate accord, which calls not only for reductions in greenhouse emissions, but also efforts to adapt to a warmer world.

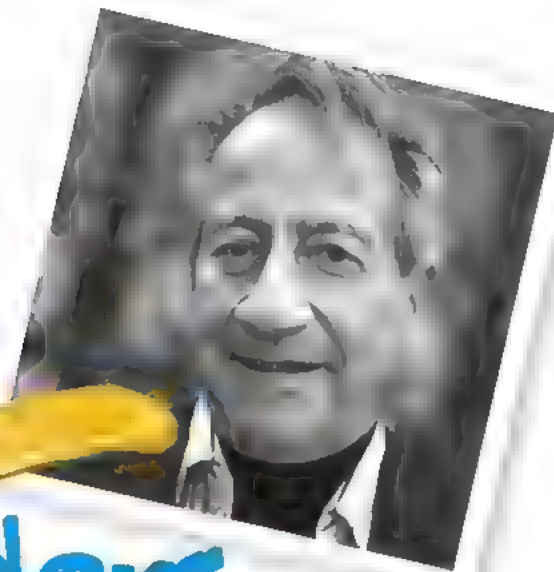
We may be witnessing a revolution in the way humanity deals with the inevitable uncertainties of life in a complex world. Prediction is giving way to adaptation. If so, it's a case of back to the future. Our knuckle-grazing ancestors never kidded themselves they knew what the future held. They just adapted to whatever their gods hurled their way, from floods to ice ages. It's taken us 10,000 years to realise they were right.

Still, better late than never. **Q**

Robert Matthews is visiting professor at the University of Birmingham

ILLUSTRATION: JON DAVIES/DAZ

Dr Saunders strikes back



Psychiatrist suffers stroke, then analyses symptoms to help others

Dr Tony Saunders always looked after his health, so it seemed doubly unfair when he collapsed with a major stroke in the gym.

Tony's family were worried that he could die, as stroke takes a life every 13 minutes in the UK. And it's the leading cause of severe adult disability.

Fortunately, with excellent treatment, Tony eventually returned to work.

But Tony noticed that discussing his stroke made him anxious – he even started stuttering.

As a psychiatrist, he identified this as post-traumatic stress disorder. He then realised that, on top of his medical training, he now had valuable first-hand experience of stroke.

So Tony struck back by overcoming his anxiety, and giving talks to medical students. As a result,

a new generation of doctors are supporting their patients with powerful new techniques.

This is Tony's legacy. And now you can strike back against stroke too, by leaving us a legacy of your own.

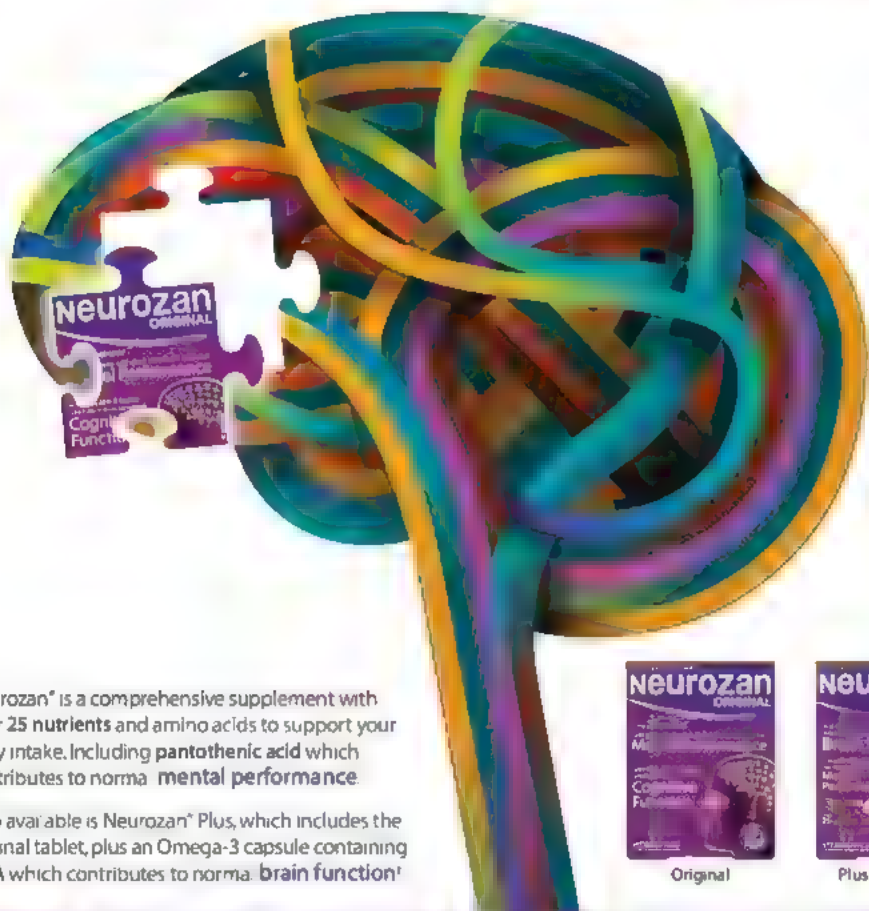
Stroke

association

Together we can conquer stroke.

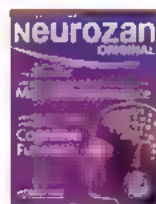
Call 020 7566 1565 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

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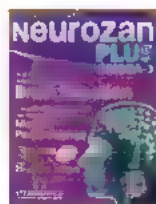


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MEAN MACHINE

To kick off the 'Summer of Mars' events programme at the Kennedy Space Center in Florida, NASA recently unveiled an amazing concept of a Mars rover that wouldn't look out of place in the Batcave.

The vehicle consists of a detachable rear section housing a science laboratory and a front section that is

equipped with radio and GPS. Sadly it is only a concept: according to the latest information on NASA's website the actual rover used in the Mars 2020 mission is likely to be similar in size and appearance to Curiosity, the 3m-long rover that has been exploring the Red Planet since August 2012.

PHOTO: NASA

1



2



6



3



4



5



WANTED

1 VIVOBAREFOOT

15 eco-friendly amphibious trainers from Vivobarefoot and Bloom Foot are made out of myco from reconstituted algal biomass, which is harvested from waterways that have a high risk of harmful algal blooms. Better than jelly shoes, any day!

Vivobarefoot vivobarefoot.com
£178

2 SNES CLASSIC MINI

The SNES is back! Available from 29 September the SNES Classic Mini is smaller than the original and eschews the cartridges, coming instead with 21 preloaded games including *Super Mario Kart* and *The Legend of Zelda: A Link to the Past*. Fun awaits!

SNES Classic Mini
£69.99 nintendo.com

3 SONY XPERIA TOUCH

Sony's ultra-compact Xperia Touch projector sends an 80cm touchscreen onto virtually any flat surface and runs on Android so you don't even have to use a laptop with it – though it has an HDMI input if you need it.

Sony Xperia Touch
£1,300 sony.com

4 SPHERO SPIDER-MAN

Sphero's new IoT-enabled Spider-Man toy will let kids tag along on missions to battle villains – even those they make themselves the adventure. And unless he's installing updates, Spidey stays offline so he's safe from snoopers.

Spider-Man interactive Super Hero
£150 sphero.com

5 PURISM LIBREM 15

If privacy and security are concerns for you, then Purism's Librem 15 or Librem 15 could be just the laptop you're looking for. It has a bespoke security-focused Linux operating system and kill switches for Wi-Fi, Bluetooth, mic and camera.

Purism Librem laptops
From \$1,699 (£1,300 approx) purism.com

6 METAXOS

The contraption may look like an exhibit from Scotland Yard's infamous Black Museum but it's actually a headphone amp. It's the perfect gift for the death metal lover who has everything. But at £6,000, it ain't cheap!

Metaxos @ Sims Margus
£6,000 metaxos.com

VIRGIN MEN

NEVER MIND THE PESTICIDES, HERE'S A BUG-ZAPPING FENCE!

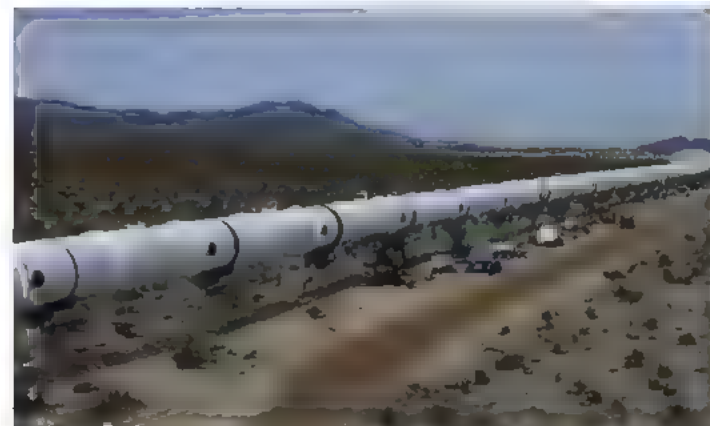
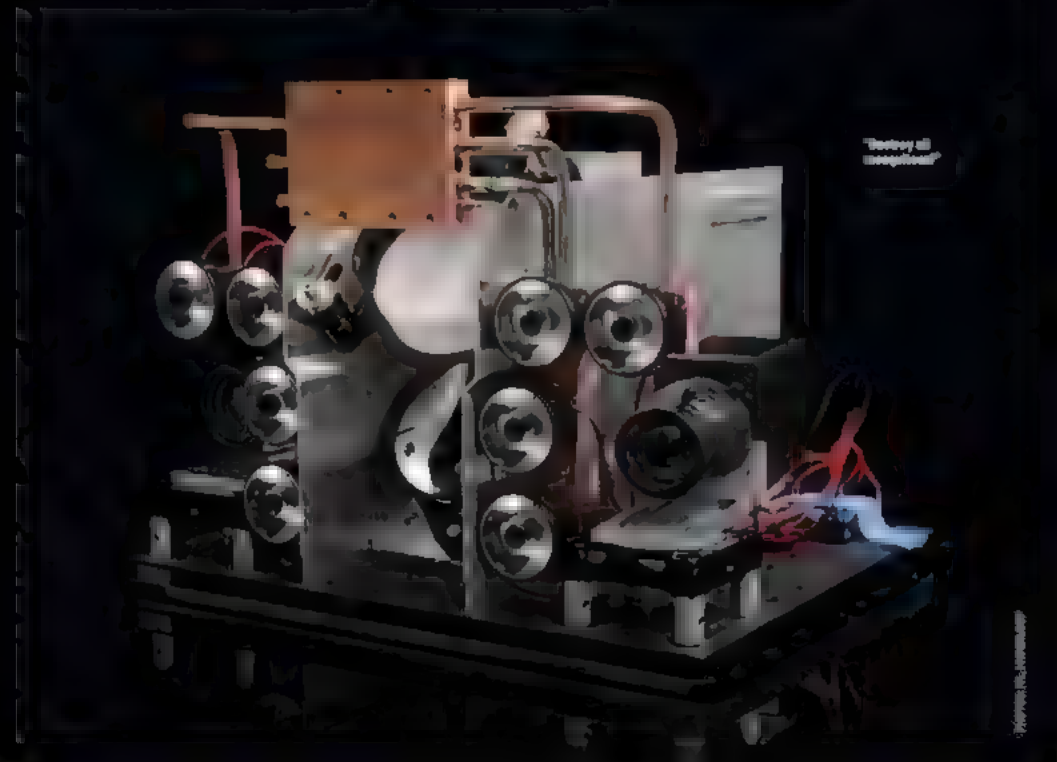
Farmers under pressure to reduce chemical pesticides can take heart from the news that the US Department of Agriculture is about to start trialling a device that can kill insects with a laser.

Developed by Seattle company Intellectual Ventures Lab (IVL), the 'Photonix Fence' isn't really a fence at all, but a small box containing lasers, cameras and an AI computer system. The cameras scan the air around the device for 100 metres, and the AI system measures the shape, speed, acceleration and wingbeat frequency of any bugs detected, to establish which are potentially harmful. Any insects identified as a threat can then be zapped by the lasers, with a 'kill rate' of up to 20 insects per second.

By deploying several such devices, farmers could effectively create a virtual fence around their crops that kills harmful pests but leaves bees and other beneficial or harmless insects unharmed.

As well as protecting crops, it's hoped the Photonix Fence could also prove useful in the fight against malaria, by eliminating only the *Anopheles* mosquitoes that spread the disease without upsetting the balance of the local ecosystem in the way that blanket use of chemical pesticides would.

The US trials will begin in August. If the device is proven to work, then IVL hopes to bring a commercial product to market, though that will still be some years away.



TRANSPORT

HYPERLOOP FOR THE UK?

Hyperloop One has announced its Vision For Europe – a series of proposed routes for Hyperloop transportation systems in mainland Europe and the UK.

First proposed by Elon Musk in 2012, Hyperloop is a hybrid electric/maglev system designed to shift people and cargo long distances at very high speeds, by placing them in pressurised pods that travel through tubes in which a partial vacuum is maintained. There are several companies and teams of scientists and engineers working worldwide to develop Hyperloop systems – including Hyperloop One, Hyperloop Transport Technologies and Transloop.

Following the success of Eurostar trains in capturing 10 per cent of cross-Channel traffic in just a few years, Hyperloop's Vision for Europe proposes routes linking Corsica to Sardinia, Spain to Morocco and Estonia to Finland. There are also suggested routes in Germany, Poland and the Netherlands, plus three in the UK.

One of these routes would link Cardiff and Glasgow, via Bristol, Oxford, London, Cambridge, Nottingham, Newcastle and Edinburgh. For this route, Hyperloop One has been working with engineering firm AECOM. A second route, dubbed the Northern Arc, has been proposed in association with architect's Ryder and engineering firm Arup, and would link Liverpool to Glasgow via Manchester, Leeds, Newcastle and Edinburgh. Finally the North-South Connector route, which has been developed in association with students and faculty at the University of Edinburgh and Heriot Watt University, would link London and Edinburgh via Manchester and Birmingham.

All three of the routes are, it should be stressed, strictly speculative propositions at this stage. But the fact that so many leading businesses and academic institutions around the world are taking the Hyperloop project seriously suggests it may be a bit of a reality sooner than we think.

TECH BYTES

CODING FOR GIRL SCOUTS

Girl Scouts in the US can now earn badges for coding hacking and cybersecurity awareness. The new badges have been introduced in a bid to encourage more young women to pursue careers in the T-sector.



CITIZENS OF SPACE

Asgardia, a 'virtual nation' set up by a Russian scientist last year, already has some 200,000 citizens. And now it's launching its own small satellite where all those citizens' data will be stored, along with Asgardia's flag, constitution and 13-month calendar.

TEMPERANCE TAG

Police in Lincolnshire are trialling a leg-mounted tag that, instead of tracking the movements of low-level offenders, monitors their alcohol intake. It's designed to ensure offenders stick to booze-free conditions imposed as part of a community sentence.



HEALTH

A HEADBAND TO TREAT DEPRESSION?

A South Korean team has developed a headband that they claim will liberate sufferers from the grips of depression. The device, called Moodi, works using a battery-powered transcranial direct current stimulation (tDCS). Here, a low-voltage electrical current is applied to specific areas in the brain via electrodes placed on the skull.

tDCS is not new – the basic principles have been understood since the early 19th Century. But the past few decades have seen increased interest in its use in treating neurological and psychiatric conditions, and a 2016 meta-analysis of hundreds of studies concluded that it's "possible or probably effective" as a treatment for depression.

tDCS equipment can stimulate

particular brain regions either actively, by increasing neuronal activity, or passively – decreasing excitability. The Moodi headset applies anodal stimulation via electrodes in the headband to the frontal lobe – an area where decreased activity is associated with depressive disorders. Moodi is not intended as a DIY solution: patients would need to be prescribed, and all data regarding treatment would be sent automatically to their doctor.

The headband is currently undergoing clinical trials at Harvard Medical School, and at 12 hospitals in South Korea. Early results are said to be promising, and if all goes well Ybrain hopes to market the device to health providers by 2019.

AVIATION

HELICOPTERS: NOW WITH WINGS!

At the recent Paris Air Show, Airbus was showcasing its new Racer concept helicopter, which has both a main rotor and a pair of propeller-driven wings. Racer is a concept for RApid and Cost Efficient Remote-tended – wind-tunnel-tested vertically – and the Racer concept helicopter, the world's fastest, is expected to reach a top speed of 400kph (250mph), which is comparable to rotary choppers. If you're getting the sense of a vehicle that's been re-engineered, Racer is essentially an updated look at the X-concept that Eurocopter, now Airbus, took to the Paris Air Show in 2011.

The craft is designed for the operation of high-speed passenger services, particularly between urban centres (such as London and Berlin) where a vertiport takes off and landing capabilities. It is also designed to travel between airports. But it could also find a role in military research and rescue operations. Airbus hopes to have a commercial craft based on the Racer concept available by 2020.



PHOTO: ORAN ERDO



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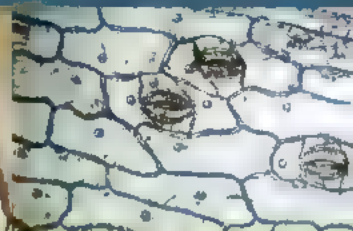
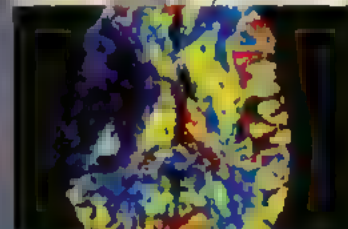
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Your opinions on science, technology and *BBC Focus*

Brushing up

I was fast in awe by your article about the work of Prof Richard Muller on the origins of time (May p.38). I like the idea that time is made as a series of 1000 one-second time expansions following the Big Bang. With new space-time expansions also entering into being. It occurred to me, though, that there might be many expansions entering into being now to be the same size as the last one.

This would have a bearing on the current work on dark energy and the apparent acceleration of the expansion of the Universe. If, as space expanded, the subatomic waves were actually becoming very slightly smaller over time, then the expansion of the Universe might not actually be speeding up, but only appear to be. Objects moving at a steady speed through successively smaller chunks of time would appear to be accelerating.

Do we need dark energy to explain this, or could it just be an artifact of the creation of time itself?
Tim Curthwaite-Sanders, London

👉 Your idea that time is not only created, as Prof Muller suggests, but also in variable amounts is intriguing, but I suspect many theorists will see it as a complication too far - at this stage, at least. Over the years, the idea of allowing fundamental properties of the universe like dark energy, the strength of gravity and the speed of light to vary with time has been studied, but to no real benefit - Prof Robert Penrose.

Shower writer of next issue's Message Dr. and Martin write on Month Monitor: Blood Pressure Will Monitor This

WORTH

On the flipside

In a recent Q&A (Summer p48) you answered a question by Coco Shang that indicates that work was still going on into the reason for toast to usually land butter-side down on being dropped.

This is an old chestnut, and surely any school boy will tell you that the usual reason for this occurrence is that the toast was probably buttered on the wrong side in the first place.


Peter Duckworth,
Credigion

Re the Q&A question about toast I recommend ALL scientists to read the excellent book *Eureka And Euphorias* by Walter Gratzer. On page 45, he describes a US scientist investigating this very problem who found his children's toast

always tell butter-side up. He only discovered later that his children buttered BOTH sides of their toast." Stuart Ching, via email

Trying tyres

Helen Czerski presents us with an interesting puzzle in her latest column (Summer p76). May I suggest the following explanation?



From her description, the nail seems to have entered through the thick, treaded part of the tyre and then pierced the thinner sidewall next to the rim.

When first entering the tyre the nail would drag after it a cone of stretched rubber from the inner tube, as Helen suggests – a skirt around the nail. On exiting the other side, the nail would not be able to deform the

Red-tails were featured in the tail-end of this picture.

ANALYTICAL DATA: 400 MHz ¹H NMR (CDCl₃) δ 7.25 (d, 2H, ArH), 6.85 (d, 2H, ArH), 6.45 (d, 2H, ArH), 6.35 (d, 2H, ArH), 6.25 (d, 2H, ArH), 6.15 (d, 2H, ArH), 6.05 (d, 2H, ArH), 5.95 (d, 2H, ArH), 5.85 (d, 2H, ArH), 5.75 (d, 2H, ArH), 5.65 (d, 2H, ArH), 5.55 (d, 2H, ArH), 5.45 (d, 2H, ArH), 5.35 (d, 2H, ArH), 5.25 (d, 2H, ArH), 5.15 (d, 2H, ArH), 5.05 (d, 2H, ArH), 4.95 (d, 2H, ArH), 4.85 (d, 2H, ArH), 4.75 (d, 2H, ArH), 4.65 (d, 2H, ArH), 4.55 (d, 2H, ArH), 4.45 (d, 2H, ArH), 4.35 (d, 2H, ArH), 4.25 (d, 2H, ArH), 4.15 (d, 2H, ArH), 4.05 (d, 2H, ArH), 3.95 (d, 2H, ArH), 3.85 (d, 2H, ArH), 3.75 (d, 2H, ArH), 3.65 (d, 2H, ArH), 3.55 (d, 2H, ArH), 3.45 (d, 2H, ArH), 3.35 (d, 2H, ArH), 3.25 (d, 2H, ArH), 3.15 (d, 2H, ArH), 3.05 (d, 2H, ArH), 2.95 (d, 2H, ArH), 2.85 (d, 2H, ArH), 2.75 (d, 2H, ArH), 2.65 (d, 2H, ArH), 2.55 (d, 2H, ArH), 2.45 (d, 2H, ArH), 2.35 (d, 2H, ArH), 2.25 (d, 2H, ArH), 2.15 (d, 2H, ArH), 2.05 (d, 2H, ArH), 1.95 (d, 2H, ArH), 1.85 (d, 2H, ArH), 1.75 (d, 2H, ArH), 1.65 (d, 2H, ArH), 1.55 (d, 2H, ArH), 1.45 (d, 2H, ArH), 1.35 (d, 2H, ArH), 1.25 (d, 2H, ArH), 1.15 (d, 2H, ArH), 1.05 (d, 2H, ArH), 1.95 (d, 2H, ArH), 1.85 (d, 2H, ArH), 1.75 (d, 2H, ArH), 1.65 (d, 2H, ArH), 1.55 (d, 2H, ArH), 1.45 (d, 2H, ArH), 1.35 (d, 2H, ArH), 1.25 (d, 2H, ArH), 1.15 (d, 2H, ArH), 1.05 (d, 2H, ArH), 0.95 (d, 2H, ArH), 0.85 (d, 2H, ArH), 0.75 (d, 2H, ArH), 0.65 (d, 2H, ArH), 0.55 (d, 2H, ArH), 0.45 (d, 2H, ArH), 0.35 (d, 2H, ArH), 0.25 (d, 2H, ArH), 0.15 (d, 2H, ArH), 0.05 (d, 2H, ArH).

inner tube to the same extent as it would be supported by the outer casing. Also the nail would not travel as far through the exit hole as it had through the bearing hole.

Once the ~~head~~ the nail was flush with the tyre tread and the wheel rolled forward, the nail would be drawn back out very slightly due to the skid at the entry point being greater and therefore stronger than that at the exit point. This would result in a small internal rubber skirt at the exit point but there would still be enough of the internal skirt at the entry point to maintain the seal.

During the remainder of the journey, every time the nail head hit the ground it would be pressed in flush again, it would immediately pop back out. The movement would be very small, especially with high pressure in the tyre, and deformation at the point of road contact would be minimal. It appears this very slight movement was not enough to cause the seals to fail although as Helen says, you have to wonder

Our place on research trip sleeping trees (July 2016) went down well with the research team involved

how much farther (not further)!!
would have held up
John Pawson, via email

FIND US ON TWITTER @sciencefocus

@transworldcham shared our excitement for
 dream hunting eagles in the Summer issue
 France is naming golden eagles after
 Mark Zuckerberg and simply put to take down
 drones let us be more like France

Researcher @admirity let us know our illustration for his tree-sleep research was on the money. Thanks @Rajalockey for the pic that is exactly what we did! Proud to be part of the #SleepyTime team. [#NREM](#) [#REM](#) [#Sleep](#) [#SleepDeprivation](#)

Referencing our online interview www.fox.com, with the Angry Chat @dalahardy said: "It is good to see a chef bring a success of something other than shouting at minions or odd food combos. It is the real deal."

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**FOCUS**

EQUATIONS

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

IMMEDIATE RELIEF

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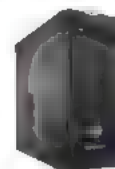
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THE NEWS IS NEVER SHORT OF HEADLINES TELLING US THAT **ANOTHER RESOURCE IS ABOUT TO RUN OUT.** BUT ECONOMIST AND CONSERVATIVE PEER **MATT RIDLEY** ARGUES THAT HISTORY SUGGESTS **OUR FUTURE MIGHT BE BRIGHTER THAN YOU THINK...**

Stolen's sea cow was a most unusual beast. The girthy, stocky, water-dwelling creature was discovered in 1741 by Georg Steller, who had his shipmates wear round lenses that blurred his vision. Located in the North Pacific,

Rhinoceros was a most unusual beast. The girthy, stocky, water-dwelling creature was discovered in 1741 by Georg Steller, who had his shipmates wear round lenses that blurred his vision. Located in the North Pacific,

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people on Earth together with their domestic animals, use a large proportion of the planet's resources. They have not, however, increased the extraction of many species. According to Prof. Hans-Harald of Austria's Klagenfurt University, about 14 per cent of all the new green vegetation on the planet is eaten by animals each year, while another 9 per cent is destroyed or prevented from growing at all. It's hard to find an ecosystem we have not affected.

For several decades, it has been a staple of the environmental movement that the end of the world is just that: the end. It is a warning of the collapse of civilization. The first worry was as the world ran out of resources, the end of the world. The Rev. Thomas Robert Malthus in his famous 1798 book *An Essay On The Principle*

"HERE WE ARE IN THE 2010s WITH VAST PROVEN RESERVES OF OIL"

● **Of Population.** For the next century land was indeed scarce. Humanity only expanded by putting the plough and the cow on to the prairies, the steppes, the pampas and the outback.

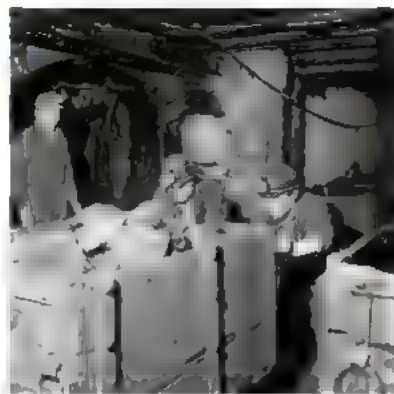
Yet the area of land needed to support an individual human shrank dramatically in the 20th Century, as tractors replaced horses, coal and oil replaced wood fuel and hay, and synthetic nitrogen fertilizer (fixed from the air) replaced manure grown on other land. Since 1960, the acreage of land needed to produce a given quantity of food has gone down by 68 per cent. Professor Ausubel of Rockefeller University calculates that even with conservative assumptions for population, technology and economic development, humanity will be able to release at least 146 million hectares from farming over the next 50 years – an area more than six times the size of Great Britain.

Such land sparing is already happening in many rich countries: New England is now mostly forest whereas it was once mostly farmland. Meanwhile, the United Nations Food and Agriculture Organization said in 2015 that net deforestation has almost ceased. "The net annual rate of forest loss has slowed from 0.18 per cent in the early 1990s to 0.06 per cent during the period 2010-2015".

In the late 20th Century, fossil fuels were thought to be in danger of running out. As long ago as 1865, the economist William Stanley Jevons predicted that the coal on which British industry depended would soon run short. In his pamphlet *The Coal Question: An Inquiry Concerning the Progress Of The Nation And The Probable Exhaustion Of Our Coal Mines* (1865), he wrote that "It is thence simply inferred that we cannot long continue our present rate of progress". He went on to say that British people "must either leave the country in a vast body or remain here to create painful pressure and poverty".

This led to the 'coal panic' of 1866. With the encouragement of political economist John Stuart

Mill, the government passed the Coal Mines Regulation Act 1872, which required that coal mines be worked in a safe and healthy manner. The act also provided for the establishment of a Coal Mines Commission, which was to investigate the coal mines and report to the government. The act was a landmark in the history of coal mining in Britain, and it led to the establishment of the Coal Mines Regulation Act 1872, which required that coal mines be worked in a safe and healthy manner.



Mill, politician William Gladstone (who later became prime minister) promised to start paying down the national debt while coal lasted, citing even a "grave and urgent fact". Something had gone badly awry in Jevons's assumptions, however. Today, the world is consuming over 30 times more coal each year than it did then, yet the amount of remaining coal is sufficient to last thousands of years at current rates of use. Under the North Sea alone, there are billions of tonnes of it. We are likely to stop using coal long before we run out of it.

Oil was the next resource thought to be in imminent danger of exhaustion. In 1914 the United States Bureau of Mines predicted that America's oil reserves would last for 10 years. In 1939 the Department of the Interior said American oil would last 13 years. President Jimmy Carter announced in the 1970s that "We are disappointed that the proven reserves of oil in the United States by the end of the next decade [1980] will be about 20 years with vast proven reserves of oil and even more approved ones, thanks to new technologies for extracting it."

Gas was long thought to be the scarcest of the fossil fuels, but not any more. In 1982, M King Hubbert, a widely admired expert on fossil fuel reserves, predicted that gas production in the continental United States would peak before 1980 and by 2020 would have fallen to minimal levels. In fact, today, natural gas production is at record levels, thanks to shale gas.

SHORT SUPPLY?

The track record for other minerals is no better. In 1970 *Scientific American* published an article by a distinguished nuclear chemist, Harrison Brown, who argued that we would have run out of

supplies of lead, zinc, tin, gold and silver by 1990. Two years later a similar prediction, verified by a computer model called World3, appeared in a best-selling book titled *The Limits To Growth*. The book argued that increasing use could exhaust known world supplies of zinc, gold, tin, copper, oil and natural gas by 1992 and would cause a collapse of civilisation and population in the subsequent century.

But a quarter of a century after that deadline, the world is extracting roughly twice as much zinc, copper and gas as it did in 1992, and almost 1.5 times as much gold and oil. *The Limits To Growth* was very influential, however. School textbooks were soon echoing its predictions. "Some scientists estimate that the world's known supplies of oil, tin, copper, and aluminium will be used up within your lifetime," said one.

In 1990 the economist Julian Simon won \$576,077 from the prominent environmentalist Paul Ehrlich in settlement of a bet. Simon had bet Ehrlich that the prices of five metals (chosen by Ehrlich) would fall during the 1980s. Ehrlich had accepted "Simon's astonishing offer before other greedy people jump in" though later claimed he

was "guided" into taking the bet while ungenerously growling about Simon. "The one thing we'll never run out of is labour," he said.

Yet the failure of these doom-mongering forecasts has not deterred others from making the same mistake. In 2007 *New Scientist* predicted that the world would run short of niobium and hafnium by 2017. It has not happened, and the price of those metals shows no sign of impending scarcity. When I read a story about a mineral running out, I look up its price history. If it's not getting rapidly dearer, then those in the know clearly don't think it is running out. The niobium price has halved since 2007, while other rare earth elements have fallen even further.

The mistake was to assume that because the reserves of these metals were small, they would not last. But hafnium is produced as a by-product of zirconium mining, so there are no reserves. Tim Worstall, a rare-earth dealer, could not conceal his disgust. "The idea that we're going to run out of hafnium, gallium, terbium, or another oft-mentioned germanium, could only be advanced by people wallowing in their own purblind ignorance. There's not the slightest



ABOVE LEFT Until the late 1960s, coal was the UK's main energy source

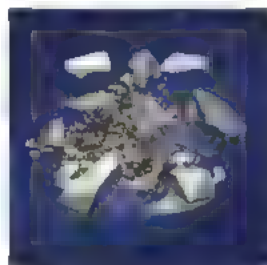
ABOVE Oil pumps at sunset in California



ABOVE Oil sand being mined in Canada. Oil sand is a deposit consisting of a mixture of clay, water, soil and bitumen. Once the oil has been extracted and separated, it can be refined to create fuel oil – it is less efficient to extract than conventional oil

RIGHT Germanium, a rare earth element, is obtained during the smelting of zinc ores. It is used for the manufacture of optics

MAIN IMAGE A mound of potash fertiliser stored at a potash mine in Unterbrunnbach, Germany



• possibility of us even running a bit short of any of them for hundreds of years.

Still, the predictions of elements running out kept coming. In 2012, Jeremy Grantham, a financier who funds climate change pressure groups, published an editorial in *Nature*. "Then there is the impending shortage of two fertilisers: phosphorus (phosphorus) and potassium (potash). These two elements cannot be made – cannot be substituted, are necessary to grow all life forms, and are mined and depleted. It's a scary set of statements. What happens when these fertilisers run out is a question I can't get satisfactorily answered and, believe me, I have tried."

He cannot have tried very hard. These two elements are never used up, they are just transferred from mines to farms. The highest-grade ores may run out, but there are vast quantities of lower-grade ones down to and including the stuff that has already been used and has ended up back in the sea or the soil. Grantham's mistake was to confuse reserves with resources. It takes money to turn a resource into a

reserve, so companies that mine phosphorus and potassium don't prove more reserves than they need for the foreseeable future.

RENEWABLE RESOURCE

This example reminds us that the distinction between renewable and non-renewable resources is confused. A phosphorus atom is renewable – you can use it over and over again. It's possible that one or two of the trillions of phosphorus atoms in your DNA were in Leonardo da Vinci at some point. Imagine Leonardo defecated, the sewage ended up in the Mediterranean where it fuelled phytoplankton that got eaten by a fish, which migrated south through the Atlantic and got eaten

by a bird which landed on an island off Africa and defecated, leaving guano in the rock that was mined in the 19th Century to make fertiliser that was spread on an English field where it got recycled through many generations of plants before ending up in you, via a burger.

Whales or woodlands, by contrast, though they are indeed capable of running out. After killing hundreds of thousands of whales in the 19th century, whalers came to find none left, then a huge number

of lost to the rack of time – saw them, took some scraps and sold what could. After burning the streams and felling the woods of Britain for energy throughout the Middle Ages, we were running dangerously short of magic sources. Then a comrade called us began to cut down our forests and to cut our rivers.

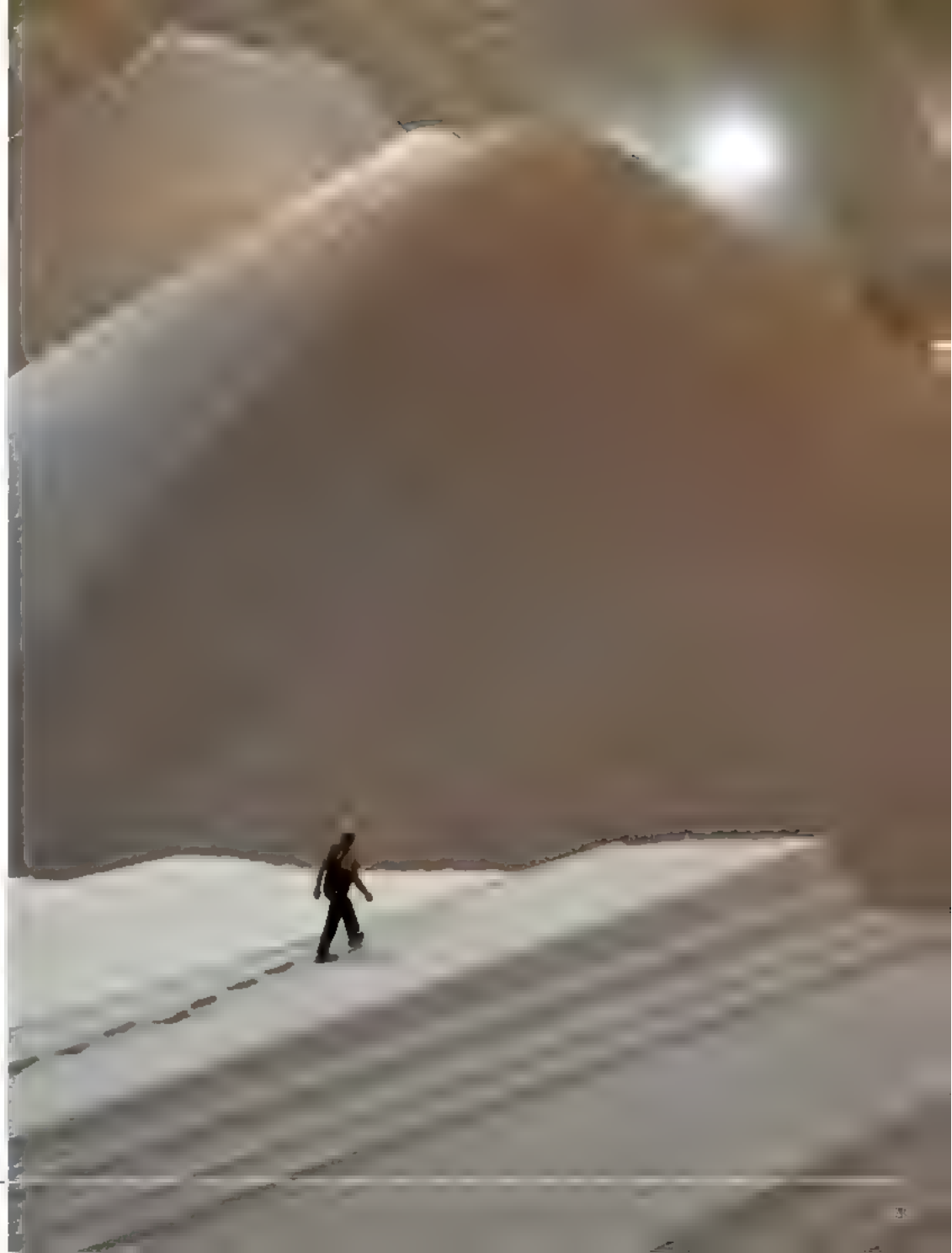
It is bizarre – a true fact that organic, renewable resources are not actually infinite. Passenger pigeons, white-pine forests, Steller's sea cows – while no inorganic resource has even come close to running out, not oil, gas or coal, not silver, copper or phosphorus, not limestone, granite or sand. As somebody once said, the Stone Age did not end for lack of stone.

STRUGGLING PLANET?

To sustain our current lifestyle, we humans require 1.4 planets' worth of resources. That's 1.4

PHOTO: GETTY IMAGES PHOTO: GETTY IMAGES

"WHALES OR WOODLANDS ARE INDEED CAPABLE OF RUNNING OUT"





LEFT More productive farms could lead to less land being taken from nature

● the number calculated by the Global Footprint Network, which defines the ecological footprint as "A measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates using prevailing technology and resource management practices." In short, we are consuming the Earth a store of food, fuel, and fibre 1.4 times as fast as it can be replenished. But upon examination this number is misleading, almost to the point of dishonesty. More than half of it consists of the land that would be needed by each person to plant trees with which to absorb their own carbon emissions. If you take the view that we can cut emissions, or find better ways to sequester them, or even cope with at least some increases in them, then the footprint shrinks and we are living well within our ecological means.

Environmentalists use a formula called IPAT: impact = population x affluence x technology. The more people there are, and the richer they are and the more technology they have, the more damage they do to the environment. But this cannot be right. Human impact has been decreasing in rich countries as a result of new technology.

For example, by switching from organic to inorganic resources (diesel instead of hay, concrete and glass instead of wood, plastic instead of leather), we reduce our footprint – that is to say, the amount of land the average person needs to support their lifestyle. By using new technology we shrink our requirement for land and water. Let's compare a person who has plastic seats in their car, say, with someone who has leather seats. The plastic footprint is the area occupied by the oil well, the refinery, the plastic factory, the car factory and so on, divided by the number of

customers they supply. The leather footprint is the farm on which the cow lived, plus the various abattoirs and factories that processed the leather again divided by the number of people who were supplied. Broadly speaking, the farm dwarfs the other footprints because it takes several acres of grazing per cow and therefore per customer. In the case of fuel, the energy density of an oil well, in Watts per square metre, is thousands of times higher than that of a wood fire.

It is no accident that wolves are increasing, lions decreasing and tigers holding their own – wolves live in rich countries, lions in poor countries and tigers live in middle-income countries.

The opposite theory to IPAT is 'sustainable intensification' – also known as eco-modernism – the idea that the more productive we make our farms, mines and factories, the less we need to poach from wild nature. Thanks to irrigation and fertiliser, including the effect of extra carbon dioxide on global greening, humanity increases the productivity of many parts of the planet, even as we pinch the big chunk of that productivity for our own needs. It is therefore possible to imagine that a century or two hence we could have nine or ten billion prosperous people on Earth, but just as much forest and wildlife as if we were not here at all. We might even have brought extinct species back. If we can read the genome of Steller's sea cow from its bones, then we might be able to revive it. ☐

Matthew Ridley is a Conservative peer in the House of Lords, so a columnist for *The Times* economist and author of *His Family Reassembled* for coal mining in Northumbria



BELOW Our population is increasing, but that doesn't have to be bad news for the planet



AN ALTERNATIVE VIEW

Richard Heinberg is a senior fellow at the Post Carbon Institute. He argues that right now we have an opportunity to alter our planet's future for the better, but we could miss it if we don't act quickly enough

Anti-environmentalists often use a three-part strategy to take their way around resource limits. First, sow doubt by cherry-picking a few instances where predictions of scarcity didn't pan out. Second, use the shaky foundation of these failed predictions to dismiss scientific evidence about resource limits. Third, advance the seductive idea that we don't have to change our behaviour because markets and markets will solve all environmental problems.

That last point sounds too good to be true, because it is. While we'll be literally never run out of non-renewable resources, there are real impacts from depletion. The harvesting of Earth's non-renewables follows the low-hanging fruit principle. Extraction industries target resources that are easy to get. As these are exhausted, miners go deeper and move to lower-quality resources that are often more abundant. But these entail higher energy and monetary costs, and worse environmental impacts. We'll feel from those costs and impacts long before we're down to the last molecule of any resource.

The oil industry offers an apt example. Decades ago, drillers focused on petroleum deposits located onshore at moderate depth, that were cheap to tap. With few exceptions, geologists no longer find such deposits. The industry focuses instead on deepwater oil, arctic oil, bitumen, and 'tight oil' that is produced by fracking.

"WE EXTRACT AND CONSUME RESOURCES AT FAR HIGHER RATES THAN ANY PREVIOUS CIVILISATION"

These resources are more expensive to extract and bring, worse ecological impacts, including spills in the environment and the consumption of other resources (for example, water and sand for fracking). Plus, thanks to more energy-intensive production, we get less net energy for society. Meanwhile, the oil industry's profits are declining and its debts are soaring. From the industry's perspective, the solution would be higher prices, but high oil prices

depress the overall economy, reducing demand. There is no longer an oil price that works for producers and consumers.

Why not recycle all non-renewable resources? We should certainly try, but recycling is no panacea. Some recycling is too hazardous, such as when products contain toxic chemicals. Sometimes there's little that can be made from a synthetic material after first use, as with many low-grade plastics. Recycling often has prohibitive energy or monetary costs. Some materials (including phosphorus in fertilisers) become so dispersed that collecting and recycling them would be impractical.

Depletion of non-renewables contributed to the collapse of past societies. Today, we extract and consume resources at far higher rates than any previous civilisation. This is possible due to cheap energy from fossil fuels, which enables us to mine, transform and transport oil resources in ever-greater quantities, even as resource quality declines. But fossil fuels are depleting too. Some say it won't be easy to run industrial societies without extracting ever more non-renewable resources. Yet we have no choice. Depletion will bite harder every year until we make recycling non-renewables easier, use fewer toxics, and transition to renewable resources for most purposes, especially for energy. Once the transition is accomplished, we'll no longer be vulnerable to the economic and environmental consequences of non-renewable resource depletion, such as climate change and pollution. Wind and solar power is often cheaper than electricity from fossil fuels, and the public overwhelmingly favours renewables and recycling.

Opportunity waits, but not forever. ☐

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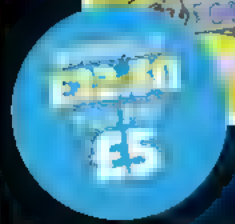
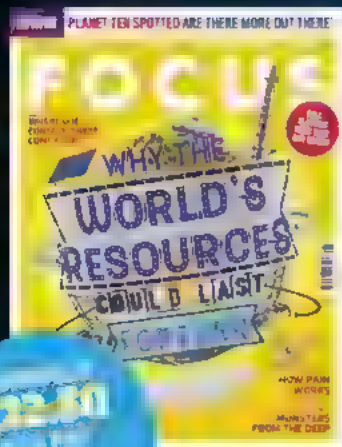
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THE FUTURE OF FIGHTING CRIME



can't make a mind-blowing waitlist. Scientists are
not just developing new ways to catch them in the spec-
ies, but also using advanced technology to help them.

WORDS: ANDY RIDGWAY

PREDICTIVE POLICING

CAN WE PREDICT CRIMES BEFORE THEY HAPPEN?

It's 4:30am on a Friday morning in August, and he's a heavy police presence in a quiet London suburb—a respectable leafy area and right now nothing's happening. In fact, it's been quiet for the past few days. But the officers are on high alert. They've been sent to the scene of a computer that calculated on the basis of the data fed into it that a wave of break-ins is highly likely within the next 24 hours. In other words, they're policing crimes that they think will happen rather than ones that have appeared. This is predictive policing. And it's about to get much, much more sophisticated.

The idea is predicting where crimes will take place on a few. For decades now, police forces in the UK and US have been creating 'hotspot' maps that identify the areas where most incidents are taking place, and then sending more police officers to those areas. Predictive policing takes this to the next level, crunching big data using algorithms based

on those that help to predict when and where the next earthquake aftershock will be, or how a disease will spread.

These algorithms generate information that police officers can act on and it seems to work. In tests, the predictive powers appear to outperform the more traditional techniques used by crime analysts. These successes have led to predictive policing being adopted by several US police departments, such as California and Arizona, as well as Kent Police in the UK.

But not everyone's convinced about predictive policing—or how it's implemented at least. Among them is criminologist Prof John Eck at the University of Cincinnati. His problem isn't so much with the predictive policing software itself, but the idea of sending a large number of staff to patrol problems highlighted by the algorithms. "Why would you want to keep sending a large number of expensive public servants to

these locations?" he says. "Instead, we should be asking why this location has a consistent crime problem, and what we can do to keep it from happening." Eck would prefer if the police encouraged owners of

businesses and other properties highlighted as crime hotspots to step in and make changes, such as shops with high shoplifting rates reducing display heights. Critics have raised other concerns, too, such as the possibility of crimes simply moving to other locations when problem areas are targeted by the police.

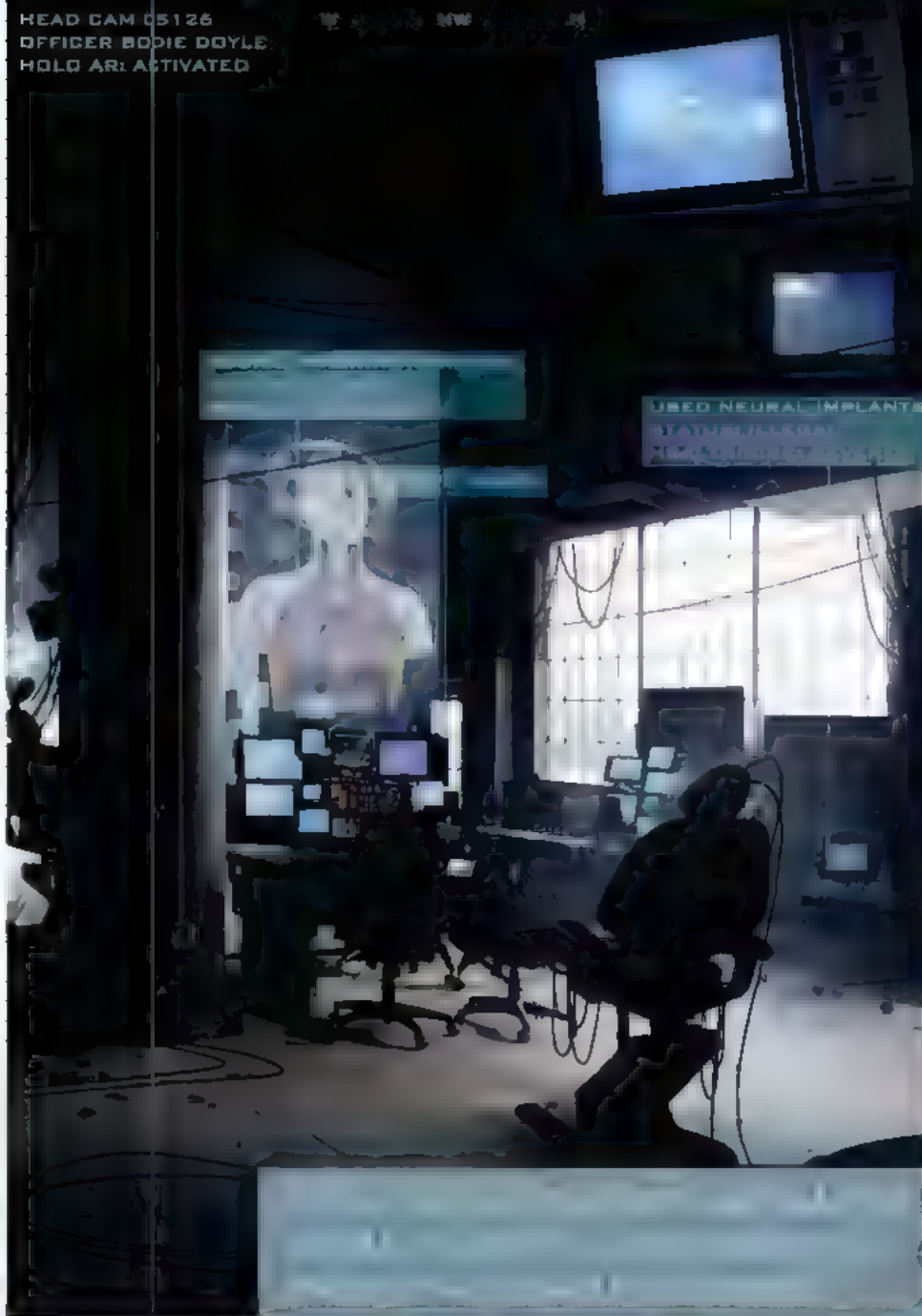
But predictive policing is becoming more and more widespread, and it could be about to change radically. Earlier this year, a bunch of mathematicians led by Prof Mark Giordano at Imperial College London were awarded £1m from the government to take

predictive policing to the next level. Whereas today's tools just rely on the data, such as the locations, dates and times of incidents, Giordano and his team will be working in how to integrate the likes of Twitter feeds, newspaper reports and social media data to sharpen the predictions. Text documents will be analysed and coded into numerical representations with counts of words and phrases—such as descriptions of assaults or break-ins—to highlight geographical areas of concern. All of these statistics of

information will be coded and integrated using software called 'naïve Bayes', says Giordano, referring to the complex maths that would allow all of this disparate data together.

What's more, this new predictive tool aims to work out the extent to which crime will be displaced to a neighbouring area when the number of police in the original area suddenly shoots up. "Our models will be able to propagate what would happen," says Giordano.

HEAD CAM 05/26
OFFICER BODIE DOYLE
HOLD ARM ACTIVATED



AUGMENTED CRIME SCENES

Being the first police officer to arrive at a crime scene is a stressful business. Are the suspects still there? Is it safe for me to walk around? Does anyone need medical help? In these circumstances, it's easy for what might take time to be a vital piece of evidence to be pointed in some way, or hidden or knocked over, or mishandled. But soon, officers arriving at such scenes may have the next minds in crime scene investigation to guide them every move, even if they're working at the other end of the city.

The idea is to use augmented reality where a view of the real world is augmented in some way with digital data. Researchers at Delft University of Technology in the Netherlands have been working with Dutch police, the Netherlands Forensic Institute and the Dutch Fire Brigade to develop a system in which crime scenes get overlaid with information from a database so easily, you know who to bag up as evidence or investigate further.

In one recent trial of the technology, officers were faced with a mockers' slay-fab in the kitchen of an apartment. A smartphone mounted on an officer's shoulder beamed live video to a crime scene investigator who then annotated what they could see, highlighting the chemicals and equipment that would need to be removed for analysis. The officers on the ground viewed the scene and annotations through a second smartphone they were holding, and, in another test, the smartphones were replaced with augmented reality headsets.



PHOTO: GUY LAWRENCE/REUTERS/GETTY IMAGES

Staff from the University of California, Berkeley, are working on predictive policing software.

EXTRAORDINARY EVIDENCE

Even the tiniest scraps of evidence can help to catch a criminal

GUNSHOT FORENSICS

Gunshots ring around a city centre street. One man lies dead in the road and another tells the police he fired his gun in self defence after being shot at. No one saw what happened. The one thing the police do have is video footage from a mobile phone, while it doesn't actually show the shooting, the sounds of the gunshots have been captured. Dr Robert Maher at Montana State University is the man to call. By firing assorted weaponry near a semicircle of 12 microphones, he has developed a database of soundwaves produced by different guns. The aim is to enable different gun types to be distinguished from a sound recording, helping police unpick exactly what went on in cases like our shoot-out.



GENETIC MUGSHOTS

Scars, a drop of blood could provide forensic scientists with all the information they need to draw the mugshot of a suspect. Researchers are starting to establish how our genes shape our faces, and if they manage to 'hack' their biological programs, it would mean that they could recreate a person's visage from a tiny DNA sample. Dr Mark Shriver, an anthropologist at Pennsylvania State University, is on the case. Working with Dr Peter Claes, an imaging specialist in Belgium who captured three-dimensional images of over 600 volunteers' faces, he analysed thousands of genes and was able to pinpoint 24 versions, or 'variants', of 20 genes that would help with predicting someone's facial shape.



SCENT OF A VILLAIN

In the future, could vanishingly small traces of perfume or aftershave on a shirt could be enough to bring an attacker to justice? Fragrances are notoriously difficult to detect because they are made up of volatile molecules that evaporate rapidly. But a team led by PhD student Simona Ghergel at University College London has found that the cocktail of compounds that make up perfumes can be transferred between clothes and subsequently detected. The highly-sensitive detection technique is known as 'gas chromatography-mass spectrometry'. In one test, when two fabrics had been in contact for just one minute, 15 out of 44 fragrance components in a male cologne were found.



WHAT'S IN A HAIR?

Give a strand of your hair to Dr Glen Jackson at West Virginia University and he can tell your age, sex, what you eat and how much you exercise. For police with little to go on from a crime scene other than a few bits of hair, this information can be gold dust. Jackson and his team measure the ratio of isotopes – atoms of the same element with different numbers of neutrons – within the 21 amino acids found in keratin, the main component of hair. So far, they have found 15 isotope ratios that provide a window into who someone is.

E. COLI
GENOME IDENTIFIED
SUSPECT ON WIN ALEX
ARMED ROBBERY
AGGRAVATED ASSAULT
VIEW FULL PROFILE

MICROBIAL FINGER-PRINTING

It's a slightly unsettling thought that each of us sheds around 10 million bacteria every hour. They wait in the air, and cling to objects we've touched – like furniture and mobile phones. The community of microbes that live on and inside us today, our microbiome, is a so unique. Soon, criminals may be linked to a crime scene by the trail of bacteria they happily leave behind. In one study, Dr James Meadow, then at the University of Oregon, found that people could be identified simply from the invisible cloud of bacteria they left in the air – even when the air was sampled four hours after they had left the room.

POLICE LINE POLICE LINE POLICE LINE

LIAR, LIAR, BRAIN'S ON FIRE

Can brain scans
reveal when
someone is fibbing?

Since 2000, neuroscientists have been using just one other MR (functional magnetic resonance imaging) technique: **arterial spin labeling**. MRI works by measuring blood flow: blood in the brain is the hardest specific region to scan, the greater the blood flow to it. Research in MRI and detection involves pumping a bunch of volunteers in a scanner and having them eat porky pies. In some instances, researchers have found the tests to be 90 per cent accurate with brain regions such as the ventricles and the hippocampus, centres springing into life and giving away the deception. And in a study published in the journal *Stroke* in Psychiatry in 2016, MRI was 24 per cent more likely to spot strokes than a traditional physical test.

But many neuroscientists are sceptical of fMRI's ability to detect lies. For one thing, the test seems easy to beat. In a piece of research, Harvard students were asked to lie while they were in an fMRI machine. The accuracy of the tests slumped to 33 per cent when the lying students wiggled their fingers and toes.

Designing a test that's realistic is tricky too—something that worries □ Anthony Wagner a

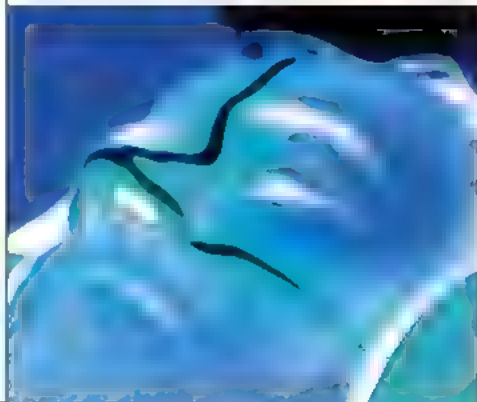


psychologist at Stanford University "is an instructed man who knows less about a meaningless event the same as a person trying to read out something they observed or an act they committed which he might could see them paying a significant fine or going to a?" he says

Such concerns haven't stopped JS, who is suing to get fMRI evidence admitted in court to prove that their client is telling the truth. Judges have refused the requests so far. "Some or late there will be a judge who will decide to go against the mainstream and allow this," says Dr. Daniel Langleben at the University of Pennsylvania. "It will be a precedent and there will be another case and another one then there will be a free fall. All it is not a good outcome."

Langleben argues that it would be better to conduct a large trial of fMRI deception to come up on issues such as how sensitive the technique is to attempted deception, such as a man wriggling their fingers and toes.

"MANY NEUROSCIENTISTS ARE SCEPTICAL OF FMRI'S ABILITY TO DETECT LIES FOR ONE THING THE TEST SEEMS EASY TO BEAT"

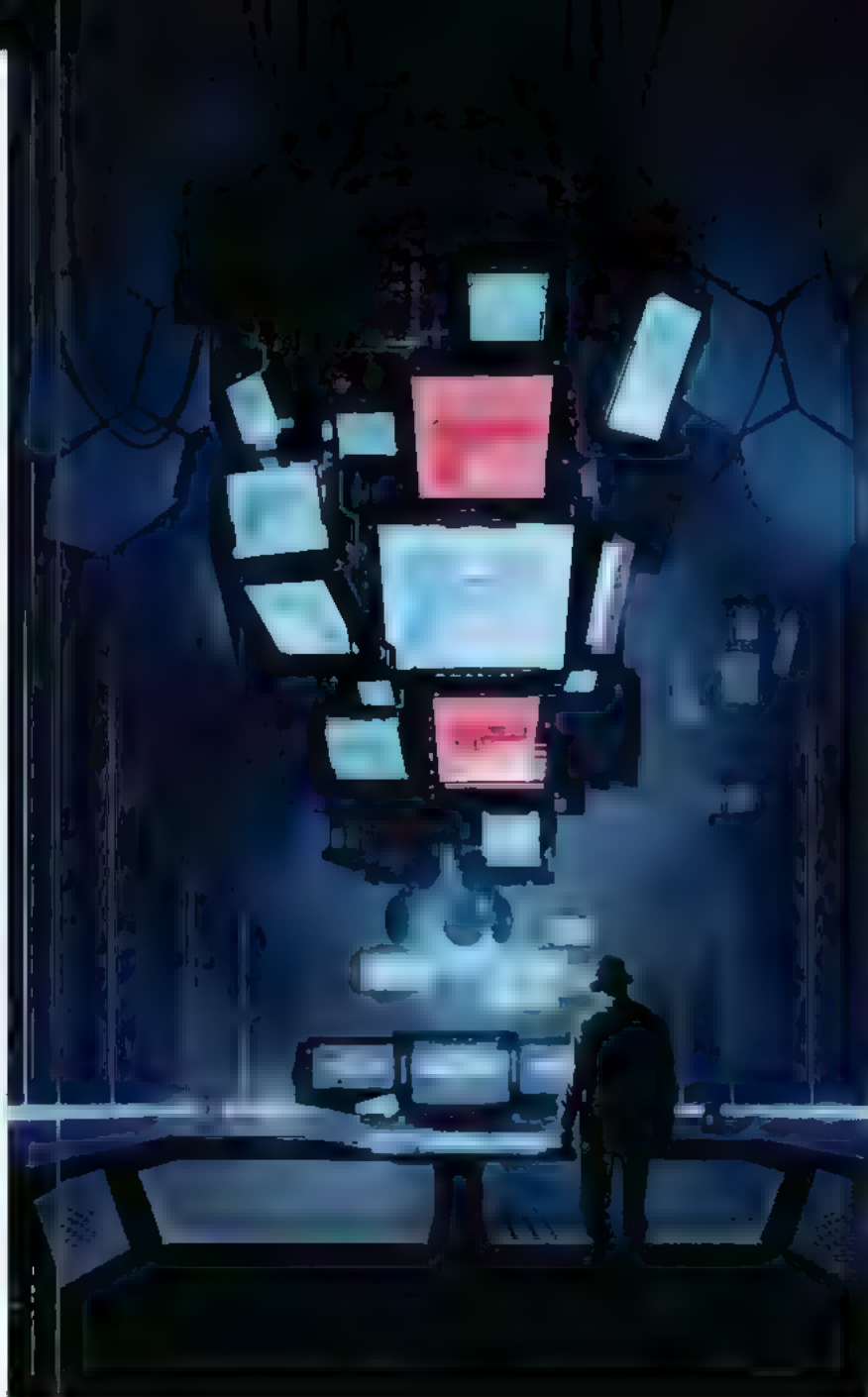
[illegible]A DETECT _{YES}

There has been a spate of armed robberies in the city. And detective V.A. Crim has been asked with scanning thousands of records of previous crimes to find patterns and connections that could help pinpoint down who is responsible. The thing is V.A. Crim is human.

VACCANO vs. Social Analytics for
 Sense making in Criminal
 Intelligence Analysis. An AI
 system that can help police
 crime reports into views,
 v. demands and queries in expressing
 words and recognising faces. Its
 aim is to identify links between
 crimes that might provide
 detectives with an
 important breakthrough.
 These links may be significant in the
 modus operandi of the
 thief, a relevant weapon or
 a minor descriptively
 witness. Initiated by the EU
 and led by Prof. William Wong at
 Middlesex University of London
 AI Crime an learn-to when a
 crime analyst decides whether a
 piece of evidence is defined by
 the system is relevant or not. It
 will use that information to
 improve face searches. It is
 current v. being used by police
 in the West Midlands and in
 Antwerp Belgium

valCR is a unique other AI systems for crime detection have been developed to do everything from finding large volumes of documents for clues to addresses to helping forensic teams determine how many people have contributed to a large multi-person DNA sample something that's tricky toathom at present

Andy Ridgway is a music-based
journalist and author of the
book *Rock & Roll: The Story of
the Music*. He is also a
contributor to the *Rolling Stone* magazine.



INTO

THE


ABYSS



With its spectacularly spiny body armour, this crab was immensely well protected as it stalled around on the seabed. Even its colour is protective, helping it hide in the dark depths between seawater that absorbs red light. "You lose it [red light] pretty quickly as you go down, so everything becomes black," says Bray. This means that red pigment appears black, which would have made the crab incredibly difficult to spot. Most deep-sea animals haven't evolved red vision – an added bonus for this crustacean.

FOR THE FIRST TIME,
SCIENTISTS HAVE
EXPLORED THE DEEP SEA
OFF AUSTRALIA,
REVEALING A WHOLE NEW
WORLD THAT'S FILLED
WITH BIZARRE CREATURES

WORDS WHEN ENJOY
PHOTOS HUGO BOUARD / ASHER PLAT / CES RE



was a good husband and a good father.
 When he was with us, he was a
 man in the house. He
 was a good father and a good husband.
 When he was with us, he was a
 man in the house. He was a
 good father and a good husband.
 When he was with us, he was a
 man in the house. He was a
 good father and a good husband.

Along the way, the team led by Jim Hartzel and Margaret Hartzel mapped the various ways that people interacted under water with a variety of devices, such as video cameras, sonar, and every kind of tool you can think of. And he says he took down a lot of the science and clinical data, "makes you appreciate what you're doing," says Brady. "I wish I had a lot of money to do what you're doing."

[illegible]

thousands of an man, collected
 perhaps three new women
 although we are not a friend
 who to each new he has
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 his new wife is going he for
 people who are yet born who will ask
 question that we can't yet answer
 using methods that we can't imagine
 any day



▲ LIZARDFISH

Two menacing lizardfish were collected on the trp. from a depth of 2,500m (16 miles). "It has just nasty, nasty teeth," says Bray. Huge eyes help them detect the faint glow of bioluminescence, which is a form of light made by many marine animals. Lizardfish are hermaphrodites, which means they have both female and male sex organs. This is a great reproductive strategy in the vastness of the deep sea, as the fish don't have to worry about finding a partner of the opposite sex when they want to reproduce - any member of the same species will do.

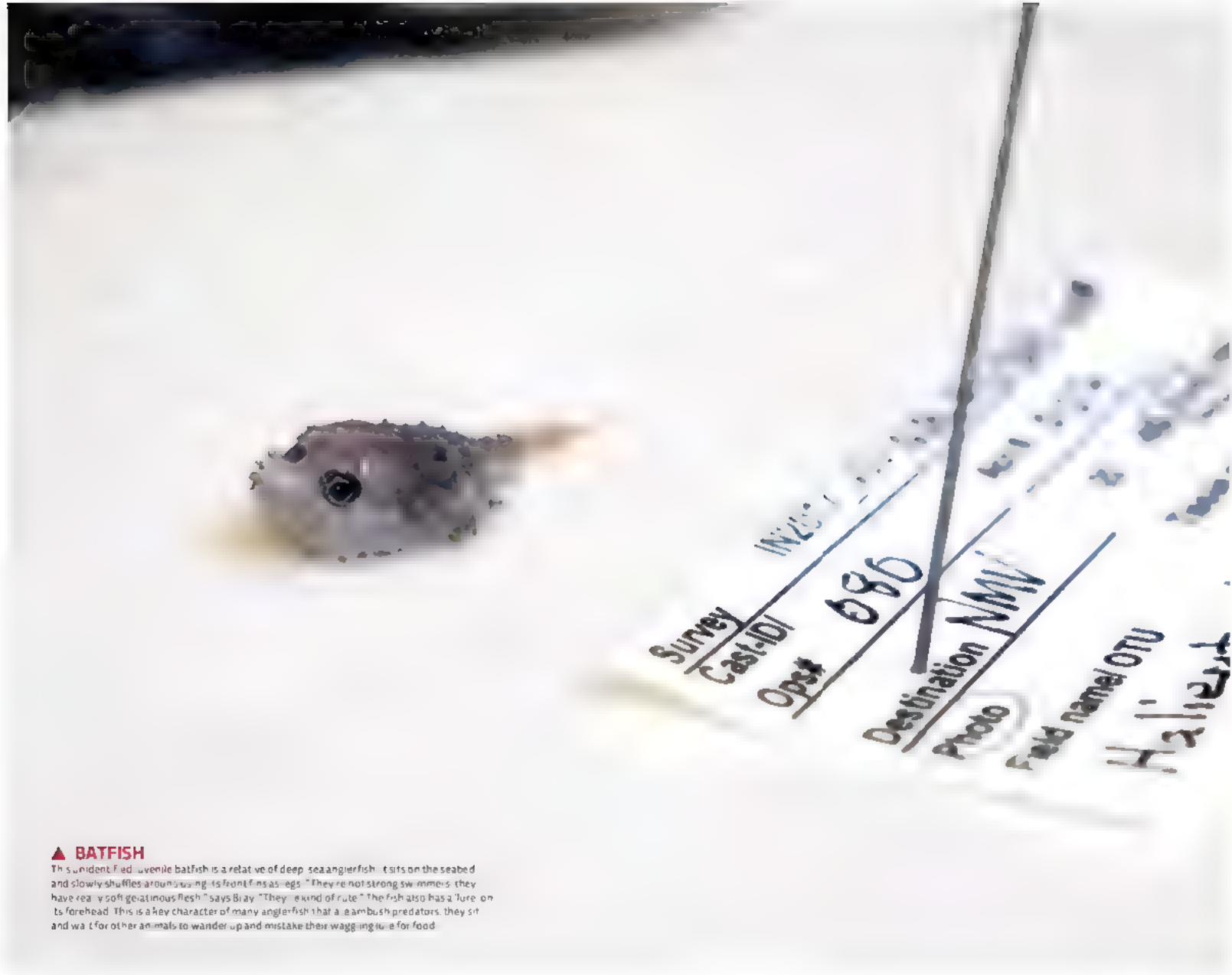
◀ GELATINOUS CUSK EEL

This fish lives in the permanent dark and has tiny eyes that may not work well. Yet somehow, it finds mates in the inky depths and gives birth to live young. The research team found another cusk eel species, which they nicknamed the 'faceless fish'. But it turned out not to be new to science. The species had previously been collected 140 years ago in the northern part of the Coral Sea, on the historic voyage of the British ship HMS Challenger, the world's first round-the-world oceanographic expedition. The new specimen is already on display to the public at the Museum Victoria.

COOKIECUTTER SHARK ▶

These fearsome sharks are rarely seen alive, but are mostly known from the circular wounds they leave in their prey (hence their name). They spend their days in the 'twilight zone' 1,000m down, then rise up at night to hunt in shallower waters. The sharks measure about half a metre in length, and latch onto large fish, dolphins and whales, before slicing out a plug of flesh with their razor-sharp teeth. Cookiecutters glow in the dark, which eliminates their shadow in the dim blue light of the twilight zone. A dark band on their skin may fool their victims into thinking they're smaller prey fish, which lures them within striking distance.





▲ BATFISH

This unidentifed juvenile batfish is a relative of deep-sea anglerfish. It sits on the seabed and slowly shuffles around waving its front fins as legs. "They're not strong swimmers; they have really soft gelatinous flesh," says Bray. "They're kind of cute." The fish also has a lure on its forehead. This is a key character of many anglerfish that are ambush predators; they sit and wait for other animals to wander up and mistake their wagging lure for food.

▼ PEANUT WORM

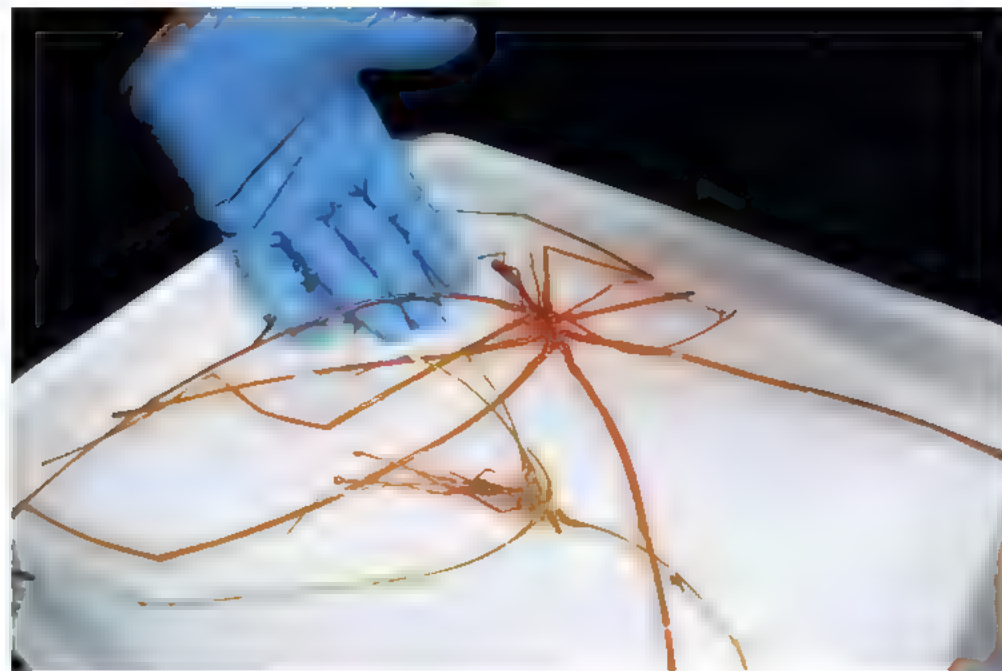
Let's face it...we're all thinking the same thing. But this is not a penis worm (although they do exist: a whole phylum of penis worms lives in mud in shallow seas). This worm belongs to a different group of seabed dwellers, called siphonophores. They can retract the front part of their bodies when they're threatened, making them look more like peanuts. There are male and female peanut worms, which can either reproduce sexually by releasing sperm and eggs or asexually by splitting themselves in half to produce identical clones...handy if they can't find a mate.





▲ CORALLIMORPH

These invertebrates belong to the same group as anemones and corals. They have tentacles and stinging cells, called nematocysts, for snagging small prey. Unlike more familiar reef-building corals, corallimorphs don't secrete a calcium carbonate skeleton and they don't form colonies. Countless other spineless creatures were brought up in the expedition's sampling nets, and preserved specimens will be sent around the globe for experts to fully identify. But it's still too soon to say how many species are new to science. "In terms of invertebrates, that's a fair way down the track," explains Bray.



▲ SEA SPIDER

If you suffer from arachnophobia, relax. These knobby kneed creatures aren't actually spiders but a separate class known as pyrosomids. They've been around for hundreds of millions of years, and simplicity is the key to their success. "They're a legs and no body," says Bray. They have no gills or digestive organs, and use a proboscis to suck the juices from anemones. Tiny sea spiders inhabit rock pools around the UK, but down in the deep, giants can have 60cm leg spans. They walk across the seabed and occasionally drift spread-eagled on the current. Males carry fertilised eggs glued to their bodies.



▲ COFFINFISH

The coffinfish sucks in water when it feels threatened and blows itself up like a balloon. This makes it appear bigger so predators might leave it alone (pufferfish use the same tactic). Similar fish have been found elsewhere in the deep sea, including Indonesia, Japan and Hawaii. But this is a first sighting for Australia. Bray explains that she'll need to X-ray it and possibly sequence its DNA to find out whether it's the same species. "It would be really cool if it's actually new," she says.

Dr Helen Scales is a marine biologist and author of *Deep Sea: The World's Most Extreme Environment*. She is a member of the expedition.

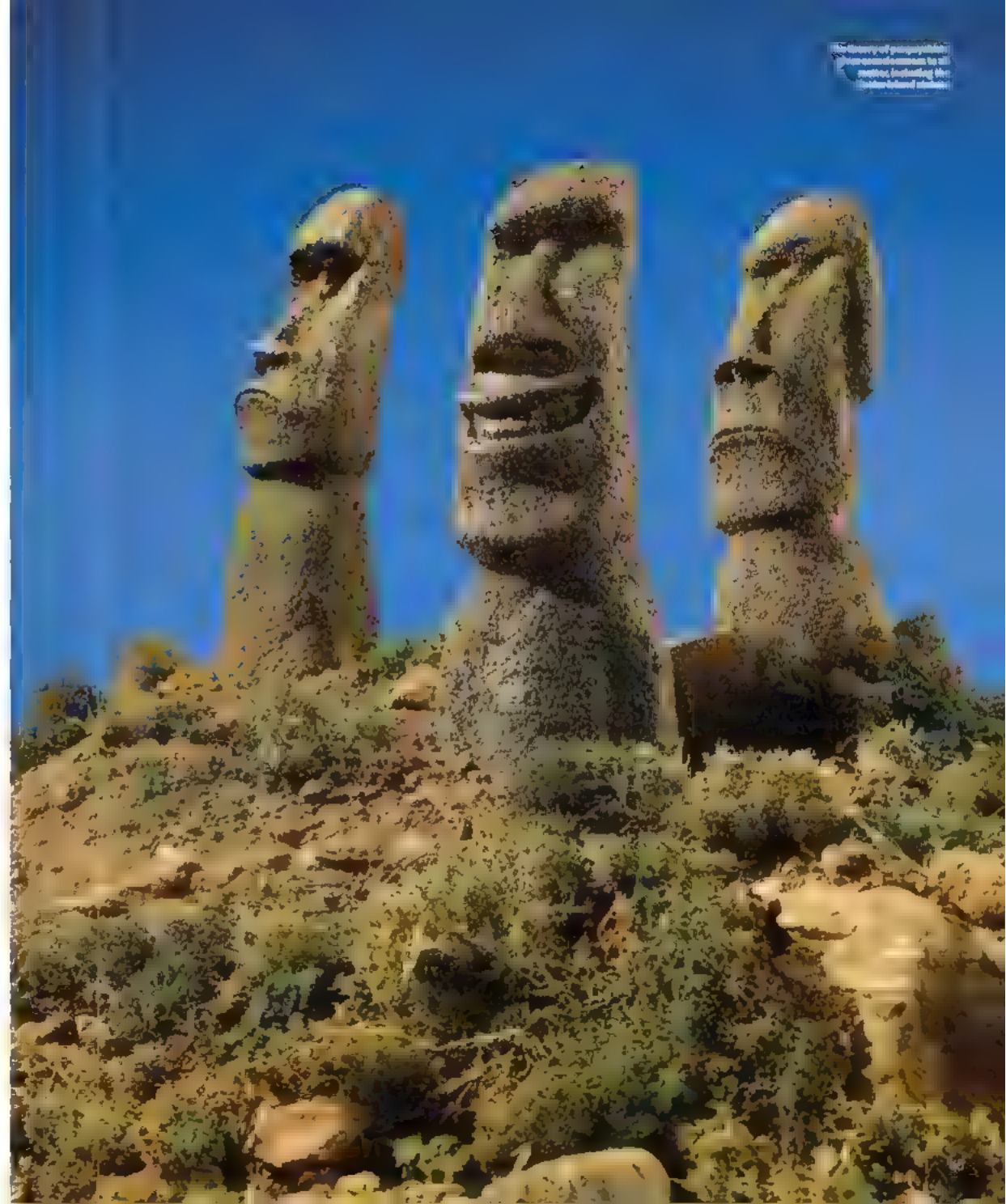
Panpsychism – the idea that all matter, including rocks and particles, is conscious – is growing in popularity. Why? Because this theory may answer one of the biggest questions in science

WHERE DOES CONSCIOUSNESS COME FROM?

WORDS: PROF YUJIN NAGASAWA

Yujin is a professor of philosophy at the University of Birmingham. His new book *Miracles: A Very Short Introduction* will be out in November. He tweets from @yujin_nagasawa

Art by O. J. Kim



For more on this and other topics, visit www.bbc.com/news/science-environment

Welcome to the world of *W*!

1. The first step is to identify the key components of the system. This includes understanding the hardware, software, and data involved. The next step is to define the requirements for the system, including performance, security, and scalability. Once the requirements are defined, the next step is to design the system architecture. This involves determining the overall structure of the system, including the components and their interactions. The final step is to implement the system, which involves writing the code and configuring the hardware. Once the system is implemented, it is important to test it thoroughly to ensure it meets the requirements and is secure.

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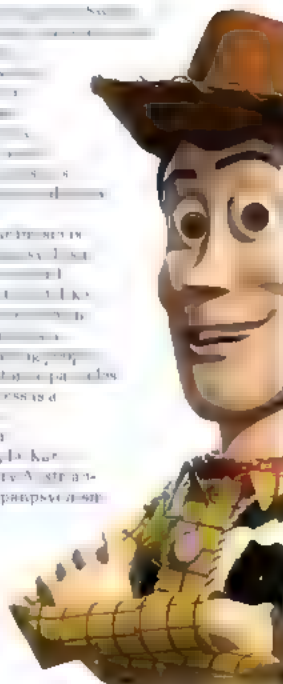
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Материалы, относящиеся к
описанию бытия, не имеют
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применения в физике.

However, some scientists and philosophers have recently come to think that psi or psychism may offer a solution to one of the greatest mysteries concerning our existence.

BELDW
Conscious
toy? The idea
may not be as
fictional as it
first appears



CONSCIOUS MYSTERY

In HG Wells's short story *The Country Of The Blind* a man in a storm called Nuvie2 arrives at a hidden valley that is cut off from the rest of the world. The valley is occupied by a population of congenitantly blind people. Nuvie2 is sure that he has a far better sense called sight but no other believes him. After staying there for some time he feels pity even as the total darkness. The characters, a sweaver, cheat by their marriage because Nuvie2 is embarrassed with the non-existence of his sense. He is a critic against Nuvie2's views, which are causing his distress. It is impossible to really imagine the even in principle for Nuvie2 to make his point, as the country comprehend what it is like to see things?

Wittgenstein is a committed epistemologist. He thought experiment introduced in 1982 by the philosopher Frank Keenan at the Australian National University which vividly illustrates the dangers of reason-ness. Imagine Mary, a brilliant philosopher, who has always lived in a black and white town. Although she has ever been outside her room in her entire life, she has learned everything there is to know about reality by studying physics, chemistry and learning what to look for in a textbook, books and lectures on black and white theory. She knows exactly how the brain works and what kind of neural processes takes place in any given situation. Suppose now that Mary is moved to town for the first time in her life. She looks at a purple dot. It seems reasonable to think that she will say, "Wow, this is what it's like to see red!" She will be so astonished now. This seems to suggest that some knowledge can only be attained by conscious experience.

The brain is a highly complex system with the unique ability to process information and to store it in organized areas or subsystems. It is not so much a unitary, or singular, entity as it is a collection of parts. What the theories about the brain teach us is that, somehow, the brain could be a kind of computer system, but that we do not understand the processes used for generation and respiration. How could processes in the brain give rise to the visual, auditory, and raw feelings that we experience? The shooting pain of a fall, or the smell of a perfume, or the taste of food, or the feeling of a touch are not processes that are taken from a storehouse in the brain. These are processes that are difficult to not understand. It is not possible for a computer to explain any of these.

THE PANPSYCHIST SOLUTION

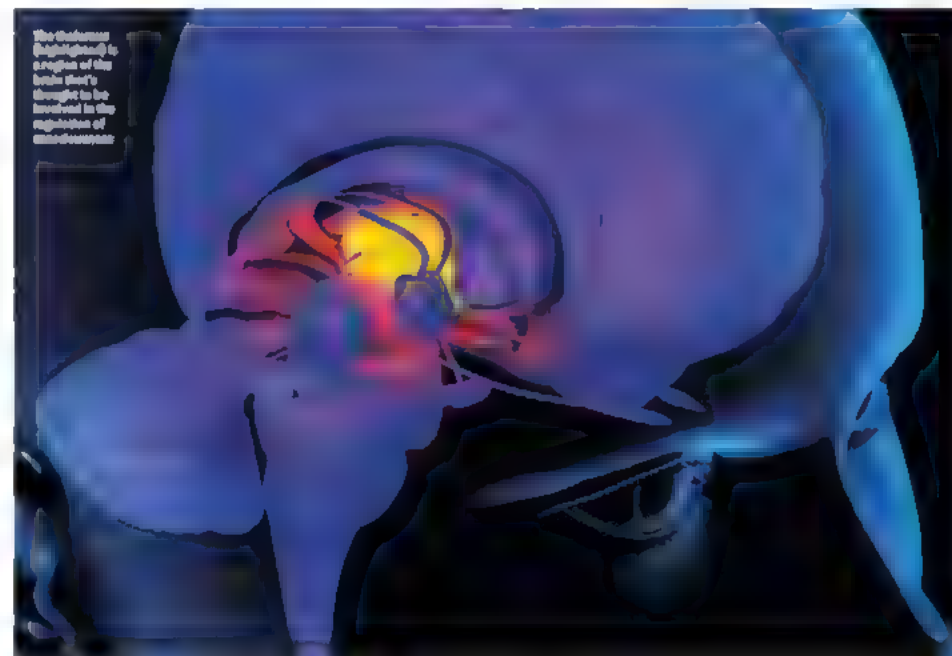
One might claim that the mystery of consciousness arises because we do not know enough about the brain. Yet the mystery is what the resources of our knowledge—where physics and neuroscience find and progress. Yet critics find such a projection too modest. Physical sciences, such as physics, chemistry and brain science, are adept at explaining natural phenomena in terms of its structure, function and dynamics of matter, objects and properties. But consciousness does not seem to be a matter of structure, function or dynamics. What if neural processes have to be accompanied by specific conscious experience? And why does consciousness

[illegible]

'According to one version of panpsychism, everything in the Universe – including people, trees, rocks, clouds and even subatomic particles – is conscious because consciousness is a fundamental ingredient of reality"



Many witnesses called attention to the fact that the defendant, who is the father of the victim, had been in the area of the crime and had been seen by the victim's mother.



The thalamus (highlighted) is a region of the brain that's thought to be involved in the regulation of consciousness.

exist in the first place? Physical scientists remain unable to answer these fundamental questions. To use a metaphor, the mystery of consciousness is about explaining the 'miracle' of turning the 'water of material processes' into the 'wine of conscious experiences'. Many scientists and philosophers have tried and failed to expose the trick for a long time.

Panpsychists try to solve this mystery by appealing to the radical hypothesis that everything in the Universe, including the subatomic particles of the brain, is conscious. They say that if the constituents of the brain are already conscious, then it is not much of a stretch to suggest that they give rise to a full-scale human consciousness when they are gathered and arranged with the necessary complexity. It is not a surprise that the 'wine of consciousness' is produced from the 'water of material processes' if the water already contains wine.

So what is the consciousness of subatomic particles? Panpsychists do not necessarily say that these particles have conscious experiences in the same way that humans do. Particles have no sensory apparatus such as eyes or ears, so they do not enjoy visual or auditory experiences as we do; they must encounter something much more primitive. That is why some panpsychists call the consciousness of these entities 'protoconsciousness'. Physical sciences postulate many fundamental features of the Universe such as space-time, mass, charge and spin. These features are fundamental because they cannot be explained in terms of more basic features. Panpsychists say that the consciousness of subatomic particles is comparable to these fundamental features. They are the ultimate building blocks of reality that ground our fully fledged consciousness. Panpsychism offers a simple yet elegant solution to the mystery of consciousness. Consciousness is not a miraculous phenomenon that arises out of nothing in the brain, but something that exists everywhere in the Universe.

Exactly how the consciousness of subatomic particles can combine to form a full-scale human consciousness is a matter of dispute. Some panpsychists hypothesise that smaller conscious experiences merge or fuse to yield full-scale human conscious experiences. Some other panpsychists hypothesise that when an aggregate of small conscious experiences reaches a certain level of complexity, a full-scale human consciousness arises as an emergent property. These hypotheses are inevitably speculative as we do not have direct access to the consciousness of subatomic particles.

Critics argue that panpsychism faces a serious problem of its own – the combination problem. The combination problem was originally introduced by William James, the so-called father of American psychology. James presents the problem with this

BELOW: Was Karl Popper, an influential 20th-century philosopher, wrong to dismiss panpsychism as nonsense?



ABOVE: Subatomic particles can help us explain the world, but could they also be conscious?

thought experiment. Take a sentence of five words say, 'It is a beautiful day'. Gather five people and assign one of the words to each person. Stand these people in a row and let each contemplate their own word as intently as possible. Is there now a consciousness of the entire group contemplating the whole sentence? No. Members of the group are individually conscious but their presence does not give rise to a unified consciousness of the entire group contemplating the whole sentence.

"Consciousness
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The point that James tries to make against panpsychism is this. If panpsychism is true, then the subatomic particles that constitute the brain are conscious. However, it seems obvious that by gathering their mini-consciousnesses we cannot obtain a full-scale human consciousness. The heterogeneity of our conscious experiences seems to contradict the panpsychist thesis that all conscious experiences are aggregates of tiny conscious experiences. The combination problem is widely considered the greatest challenge for panpsychism.

THE SOLUTION
Conscious experiences, which are smooth, continuous and homogeneous, are analogous to smooth paintings rather than to impressionist paintings consisting of distinct dots of colour. This observation leads us to a variant of panpsychism,

sometimes called 'cosmopsychism'. According to cosmopsychism, the consciousness of the entire Universe, that is, the cosmic consciousness, rather than the consciousness of subatomic particles, is a fundamental feature of reality. This view is remarkably similar to pantheism, which equates the Universe with God. Einstein expressed sympathy with pantheism when he said, "I believe in Spinoza's [pantheistic] God, who reveals himself in the harmony of all that exists."

According to cosmopsychism, our smooth continuous and homogeneous conscious experiences are segments of smooth, continuous and homogeneous conscious experiences of the whole Universe, rather than aggregates of small conscious experiences of subatomic particles. Smooth, medium-sized paintings (human conscious experiences) cannot be aggregates of distinct small dots (mini-conscious experiences) but they can be segments of an equally smooth large painting (cosmic conscious experiences).

Cosmopsychists say that consciousness is everywhere – not necessarily because subatomic particles are conscious, but because the entire Universe is irreducibly conscious. We may argue about how something large (cosmic conscious experiences) could be more fundamental than something medium (human conscious experiences), but this version of panpsychism does not face the combination problem. Cosmopsychism however perhaps stretches the imagination too far.

There is nothing more direct and certain than our own conscious experiences. The 17th-century philosopher and scientist René Descartes famously said "I think, therefore I am." We can doubt all sorts of things around us but we cannot doubt the reality of our own existence because the very act of thinking or doubting proves the existence of our own consciousness – something must be there to do the thinking or doubting. The mystery of consciousness therefore persists.

So what do I think of panpsychism as a solution to the mystery of consciousness? On the one hand I think the theory has some gaps to fill. It is unclear what conscious experiences of subatomic particles are, and how aggregates of them can yield full-blown conscious experiences. Without explaining these subatomic experiences fully panpsychism cannot be considered a successful solution to the mystery. On the other hand, it is a highly attractive theory. It tries to explain how the brain can yield consciousness by stipulating the elegant thesis that the Universe is uniformly conscious. It seems to make more sense than its alternative that full-blown consciousness suddenly came into existence through evolution in a tiny region of the purely material Universe. **E**



YOUR IDEAL PAIN
XOLORE THE PAIN
IF PAIN IN THE W/ PART
WERS NORMAL TO
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IS AN... A...
4

PAINFUL FEELINGS
From an evolutionary perspective, pain is old. It is vital because it warns us that there is something present that could cause us serious injury. Pain is subjective, and two individuals will not experience it in the same way.

PHOTO: JEFFREY



UNDERSTAND PAIN

Everybody hurts, but why? We explore the science of pain

WORDS: PROFIRENE TRACEY

We may have learnt to tame it with drugs, but pain is one of the certainties of human existence. It can be both physical and emotional, ranging from a searing torment to a mild soreness. But what exactly is it, what function does it serve, and how can we really know how much pain someone is in?

What is pain?
Simple, you'd think. You touch a hot surface by mistake and it hurts like hell. You immediately withdraw your hand, rush to the tap and run cold water over it. Phew. No need to rush to A&E. But then it throbs for days, reminding you of the burn and your carelessness until the pain fades away. Lesson learned: you'll be more careful around cookers in future.

This simple incident can tell us a lot about pain. Mostly, it's a brilliant warning system. Without it, you would not have withdrawn your hand, and the injury would be much worse. Pain like this – what we call 'acute pain' – is a good thing: it's key to our survival. That's why the ability to experience pain is shared across species. A few people include plants in this, too, but as plants have no nervous system or brain, it's hard to know how they'd actually feel pain when stepped on or cut. Pain is evolutionarily old, an essential warning that something in the environment can cause us injury, harm, or even death.

Without pain, you're in trouble. We know this, sadly, because there's a rare genetic condition, which we call congenital insensitivity to pain, or

CIP, in which a person doesn't get the warning 'hurt' of pain after severely damaging themselves. Historically, they didn't survive to adulthood due to the consequences of unfeeling injury.

What does pain do?
Pain motivates us to act. Think about that hot pan again. Now imagine you'd picked up the pan before realising it was too hot to handle. Your options are to drop it and make a mess, or bear the pain until a solution is found. In an instant, you detect that the pan is hot (thermal), it's on your hand (location), it's painful (intensity), you don't like it (unpleasant), it's engaged your full attention (cognition), and you're not happy about it (emotional). That's a lot

of things, which is why pain is often called a 'multidimensional experience'.

So, what do you do? Well, from past experiences, learnt responses, and potential outcomes (like being told off for dropping the pan) you make a decision and act. Recruiting extraordinary brain-based networks, you are able to block the pain and get on with your safety. That's the key: that cold tap. Pain drives action, prompting us to run away, avoid it in the first place, or signal to others that we need help and relief.

How do we feel pain?
Just underneath our skin surface, we have an intricate network of 'pain nerve fibres' that end with special



Sometimes can amplify pain: people who are nervous at the dentist may have a harder time than more relaxed patients

Capsaicin in chillies binds to heat receptors in your mouth, which is why spicy food burns



receptors called nociceptors. When activated, these receptors send signals along the nerve fibres to the spinal cord and up into the brain, where pain, as a perception, emerges.

The nociceptors can be activated by a variety of triggers: thermal (heat), mechanical (like a knife cut or hammer blow) and chemical/irritant (for example, acid or chilli pepper). The signals then travel along different types of pain nerve fibres. Aδ, also known as A-delta fibres carry what we call 'first pain' – the fast, quick signal that tells you 'ouch' when you touch a hot pan. C fibres follow up with the 'second pain', which is the slow, constant throbbing that tells you it's still hurting. Normal touch – feeling something on your clothes or holding a pen – is carried on different peripheral nerves called Aβ (A-beta).

The transmission of the pain signal to the spinal cord is helped by other components of the nerve fibres called ion channels, and it is these that many patients with CIP don't have, which is why they don't feel pain. Therefore, targeting and blocking nociceptors and/or the transmission process is a winning way to block pain. Indeed, that's what many pharmaceutical companies are currently trying to do.

Interestingly, many nociceptors are 'polymodal' – a fancy word meaning

that different things can activate the same nociceptor. As an example, let's look at temperature and food.

How can food be painful?

Different thermal nociceptors in our body are activated by specific temperatures, giving us a painful sensation of intense hot or cold. Amazingly, these same nociceptors are also activated by various natural chemicals, giving rise to the same experience. For instance, when we bite into a chilli pepper, a chemical called capsaicin binds to the same nociceptor that's activated by painfully hot temperatures of around 42°C and above. That's why we perceive a curry as hot: the brain can't distinguish what activated the nociceptor. It just knows that your mouth is burning! Downing a pint of lager won't help either, as capsaicin is fat-soluble, not water-soluble – so consider a cucumber raita instead.

Some scientists think that plants produce capsaicin to discourage mammals from eating their fruits. Birds don't seem to react to the chemical, allowing them to eat the chillies and help with seed dispersal, which is what the plant wants.

How does the brain generate pain?
Once the pain signals arrive from

JARGON BUSTER

CAPSAICIN

A chemical found in chilli peppers that also binds to the heat receptors in your mouth.

NOCICEPTORS

Receptors on the surface of the body that detect potentially harmful stimuli, such as heat, cold, mechanical damage, and chemical irritants.

PAIN NERVE FIBRES

A type of nerve fibre that carries pain signals from the site of injury to the brain.

PHANTOM PAIN

Pain that is felt in a limb that has been amputated, often due to nerve damage or a gap in the nerve.

PLACEBO ANALGESIA

A pain-relieving effect caused by the belief that a treatment will work, often due to the brain's expectation of pain relief.

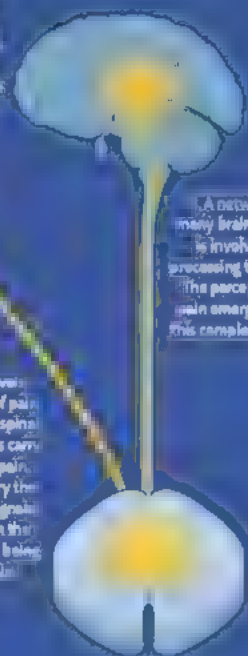


Chemical/acid

Cold

THE PAIN PATHWAY

Nociceptors detect the painful stimulus, converting it into an electrical signal. There are different nociceptors for different stimuli: heat, mechanical, chemical/acid, and cold. Some detect more than one type of stimulus.



A network of many brain regions is involved in processing the signal. The perception of pain emerges from this complex activity.

12. The signal travels along two types of pain nerve fibre in the spinal cord. A-delta fibres carry the sharp, rapid pain, while C fibres carry the slow, dull ache. Signals are modulated in the spinal cord before being sent to the brain.

WHAT WE STILL DON'T KNOW

1 HOW WE DETECT A PINPRICK

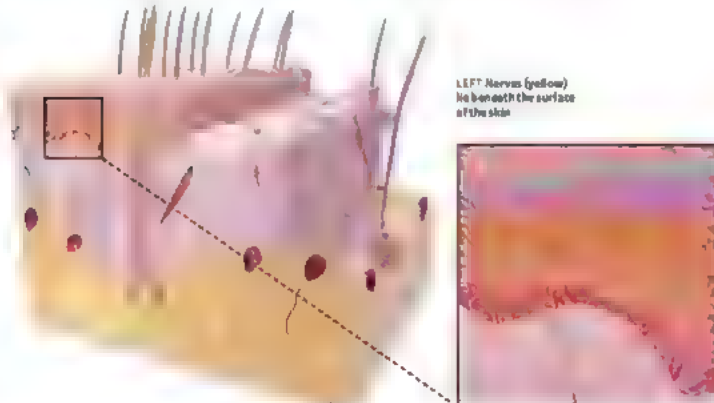
Using molecular biology and various natural chemicals as 'probes', we've identified most of the nociceptors in the body that respond to painful events. However, we're still missing the nociceptor that detects a painful hammer blow, knife cut or pinprick. Several research groups are on the hunt for this elusive nociceptor.

2 WHY PEOPLE DEVELOP CHRONIC PAIN

In chronic pain, the A-delta and C fibres often switch on permanently, causing non-stop agony. If we can work out why this happens and manage to prevent it, we'll have gone a long way to helping millions of sufferers. Also, we still need to understand why, after the same injury, one person can develop chronic pain, but the other person does not.

3 WHERE THE 'HURT' IS IN PAIN

It's thought that Oscar Wilde once said: "I don't mind pain, so long as it doesn't hurt." Funny, yet spot on. We know that the perception of hurt emerges from a network of brain regions activating together, but we still don't know exactly how this activity produces the 'hurt' of pain. Brain imaging should tell us more.



LEFT: Nerve (yellow) lies beneath the surface of the skin

PHOTO: GETTY IMAGES/PICTOLIBRARY

ILLUSTRATION: ALICE GRADY

In one tweet...

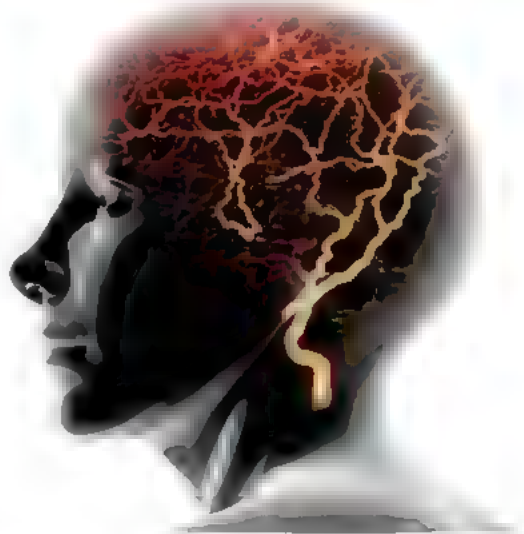
Pain as an alarm is essential for survival. Chronic pain is bad and millions suffer, but scientific discoveries bring hope

● The spinal cord to the brain, a large network of brain regions is activated. Including the brain stem, the thalamus and several regions of the cortex. The subjective experience of pain then emerges from this brain activity.

Until the conscious brain processes these incoming signals, we don't actually call it pain, but nociception – this is the nervous system's response to the original tissue damage. The relationship between the extent of tissue damage and the amount or quality of pain that the person actually feels is not a simple one-to-one mapping. Incoming signals can be amplified, attenuated or reappraised by the brain, which can dramatically change an individual's experience. So, being sad about your pain or being a victim of the dentist really will make it worse – emotions are like amplifiers in your brain, turning up the volume of pain.

Thankfully we also have an inhibitory system to lessen pain. The brain system that's responsible for the feelings of pain can talk to the spinal cord and suppress nociceptive signals like a brake. This results in less brain activity and less pain, at least until the brake is removed. This is what goes on in athletes and soldiers during situations of high arousal and battle, or when someone is distracted from their pain (for example, a parent desperately distracting their child from the dreaded vaccine jab). It's not a trick but real physiology. In fact, it's this system, called the 'descending pain modulatory system' that's hijacked when the placebo effect acts to reduce pain. This is known as placebo analgesia.

Weirdly, it was once thought, not too long ago, that because animals and babies have less developed brains than adults, they cannot feel pain. This is complete nonsense. Pain is an individualised and subjective experience that depends upon a person's mood, how much attention they give to it, the context of the situation in which they are hurt and



Pain signals arrive at the brain via the spinal cord

so on – and it doesn't need a fully developed brain to take pain.

What is the difference between physical and emotional pain?

Historically, if people reported pain in the absence of an injury, it was called 'psychogenic pain' – a pejorative term due to a flawed understanding of the mechanisms involved. Emotional pain also has a neural basis, and there's even overlap with some brain regions involved in physical pain. Understanding the basis of someone's pain is important if we're going to help them. For example, is the pain due to inputs from the body, or has the brain generated an experience independently? We shouldn't think that physical pain is more 'real' or important than emotional pain.

What is chronic pain?

This is the system gone wrong. It's defined as pain that persists beyond normal tissue healing time

– a staggering one in five adults experiences it. It lasts, on average, for seven years, but for 20 per cent of people it's more than 30 years, and is more prevalent in women and the elderly. Chronic pain wreaks suffering on patients and their families. It also brings significant costs to society, estimated annually at £200bn in Europe and \$600bn in the US. Additional problems like depression or anxiety and sleeplessness can add to the suffering.

Chronic pain is one of the largest health problems worldwide, and current treatment options do not provide adequate relief to the majority of patients. Patients with chronic pain might have different conditions. Nerve damage due to diabetes, being on chemotherapy, multiple sclerosis, sustaining an injury, phantom limb pain, or arthritis, are a few examples. Yet the signs and symptoms that patients describe are often similar. We are starting to consider chronic pain as a disease in its own right.

IN A NUTSHELL

1 NATURE'S ALARM

Pain is essential for survival, alerting us that something is wrong and that we've possibly damaged ourselves. It prompts us into action and is a great teacher – we learn to avoid things that hurt.

2 ALL IN THE BRAIN

Pain emerges from brain activity, but there isn't a simple one-to-one mapping between the amount of tissue damage and the pain we experience. It's a highly subjective phenomenon, and our emotions, attention, expectations, and context can all influence the incoming signals to strengthen or weaken the pain.

3 PROBLEM PAIN

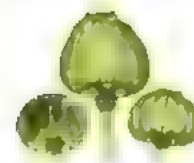
One in five adults experiences pain that persists beyond three to four months from the original injury – the definition of chronic pain. Our understanding of the biology behind this is vastly improving, so there could be new therapies on the horizon.

BELOW: A patient with multiple sclerosis has their skin sensitivity checked by a neurologist



Photo: iStockphoto.com/Robert K. Taylor

Enhanced colour X-ray of opium poppy pods



with underpinning problems (that we can work on and try to fix).

A key problem in chronic pain is that A and C fibres can switch permanently when damaged, sending constant pain signals to the sufferer's brain. Second, it's been shown that the pathway from nociceptor to brain can get 'sensitized' so that the signals are amplified. This makes the situation worse, causing even the touch of clothing or bedsheet to become painful. Imagine that, but worse, going on for years alongside additional constant pain.

How can we know how much pain someone is in?

It's important to signal when we're in pain because this drives empathy and compassion in others, as well as enabling them to offer a more beneficial environment and language to work out if someone is suffering. People groan, wince or cry out in agony. But it's hard to measure pain, as it's such a subjective experience.

Verbalising is available, then rating scales can help to quantify degrees of the pain such as intensity, unpleasantness (0 = no pain, 10 = excruciating). But I doubt your 10 is

my 10. Questionnaires can be used instead of number scales, and sometimes just smiley or sad faces such as with children. Pain levels of babies, comatose or anaesthetised individuals, or dementia patients may be more difficult to judge, and it's tough to know what they're really feeling. Looking at body measures, like heart or breathing rate, can help. Some studies suggest that women are more sensitive to pain than men, but perhaps women cope better – we all know about man flu! Brain imaging is helping us to understand pain better, but it should not be used as a surrogate for what the person reports. The International Association for the Study of Pain defines pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage". In short, if the person says they are in pain, then they are, no matter what caused it.

How do we treat pain?

Painkillers provide relief from pain. The two oldest are aspirin, which is derived from willow bark, and morphine, which comes from opium poppies. These days, aspirin is largely replaced by ibuprofen if there is inflammation, or paracetamol if there is no inflammation. Morphine is an opioid and variants of it are still widely used, but can have associated problems like tolerance and addiction. Other painkillers include different types of anti-inflammatory style drugs, antidepressants, and anticonvulsants. There are many additional treatments for pain including cognitive behavioural therapy, physiotherapy and surgery, and the most effective therapies combine all of these treatments. With new drugs coming through the pipeline, and our understanding of pain constantly improving, we can hope for a future where no one will have to suffer a necessary pain. ☺

Prof Irene Tracey's head of the Nuffield Department of Clinical Neurosciences at the University of Oxford

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IMMEDIATE

**INTRODUCTIONS
OFFER**



HELEN CZERSKI ON CAUSTICS

"THIS MEANS THE POT OF GOLD AT THE END OF THE RAINBOW IS UNATTAINABLE"

[illegible]

Curves are a sharp dividing line between bright and dark areas and occur wherever parallel surfaces are curved. Because the light reflects in a plane, it is a single-way effect. The light reflecting from an almost flat surface. When they reach the eye at a steep angle, the beam is reflected at different angles depending on what part of the curved surface they hit. But there are no curves that many of the rays get directed to those are the bright spots, so the beams are not visible. It is effectively forbidden they can't be reached by any reflection. In fact, up the two almost smooth circles more at a point called the cusp, which makes a distinct five-pointed star known as a caustic because it is vaguely kidney shaped.

Yes, we probably know some (or many) of the
 individuals who are in the "where" boxes.
 Traveling across a state or across a light rail
 or bus-rapid transit line, you'll always find
 a lot of people you know.

[illegible][illegible][illegible]

...a tremendous pattern. However, the
...here, so maybe I'll add in the
...do with that instead. ♪

Dr Helen Czetski, helen.czetski@man.ac.uk

7. $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

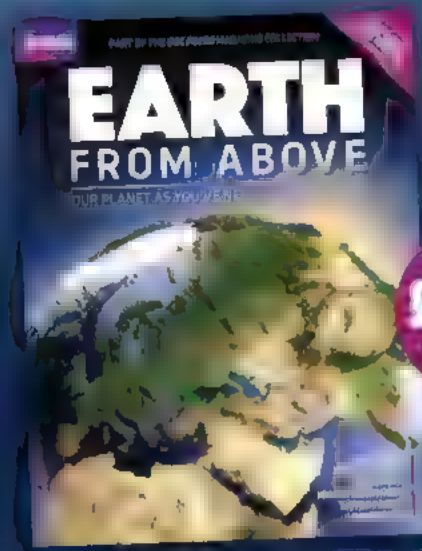
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...and the other two are the same as the first two.

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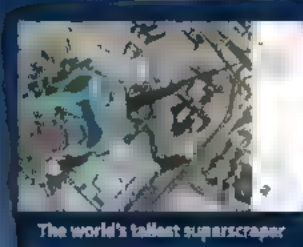


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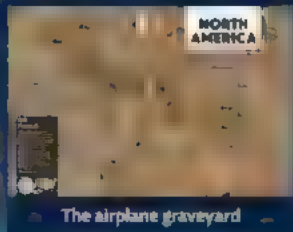
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YOUR QUESTIONS ANSWERED

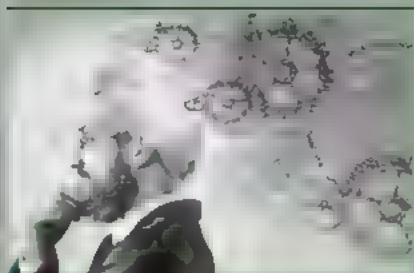
Why do rockets follow a parabola after launch?

BY NICK WILKINSON

Students have long been taught that all projectiles follow a curved path known as a parabola. The explanation is that as they fly, they cover distance both horizontally and vertically – but only the latter is affected by the force of gravity, which bends the path of the projectile into a parabola. For long-range rockets, things are more complex. For example, air resistance must be taken into account. But even ignoring that, a projectile doesn't really follow a parabola – because the Earth isn't flat. This means that gravity doesn't simply pull objects straight back down. Instead, it pulls them towards the centre of the Earth, whose direction changes as the projectile moves further down-range, away from the launch site. Detailed calculations then reveal that the true trajectory is not a parabola, but part of an ellipse.



ADH. ADEMOTTE



How many organs could you lose and still live?

ALICIA JONES, M.A. D.D., N.E.



...the most common cleaning products used in the home. The products are arranged in a row, showing a variety of colors and shapes. From left to right, there is a white spray bottle, a yellow spray bottle, a blue spray bottle, and a red spray bottle. The background is a light blue gradient.

TOMY CARTER BY ENAM

This is achieved by compressing the gas, and then expelling it through a small nozzle. As the gas expands, it rapidly cools (you'll have noticed this effect if you've ever used an aerosol deodorant). The process is repeated until the gas that remains out of the nozzle is cold enough to condense to a liquid, then if you repeat the cycle a few more times the helium will become cold enough to turn to a solid, and so on.



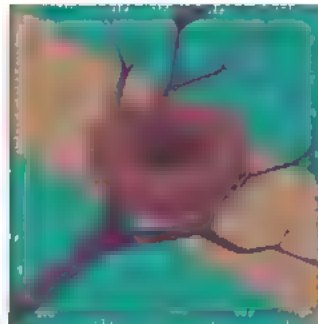
THE THOUGHT EXPERIMENT



JONATHAN HINCHLIFFE, BIRMINGHAM

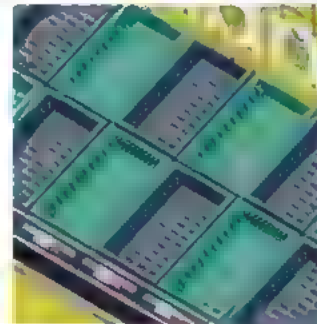
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WHAT WOULD HAPPEN IF ALL EARTH'S INSECTS VANISHED?



1. FOOD CHAIN COLLAPSE

Most non-marine food chains depend on insects. Almost all birds eat insects, and even those that eat seeds as adults still feed insects to their young. It takes 200,000 insects to raise a swallow chick to adulthood. Insects also break down plant matter and help recycle nutrients into the soil. Without any insects at all, most bird and amphibian species would be extinct in two months.



2. NO POLLINATION

Of the world's food crops 75 per cent are pollinated by insects. Without insects, we could still grow many foods, but onions, cabbage, broccoli, chillies, most varieties of tomato, coffee, cocoa and most fruits would be off the menu. So would sunflower and rapeseed oil. Demand for synthetic fibres would also surge because bees are needed to pollinate both cotton and flax for linen.

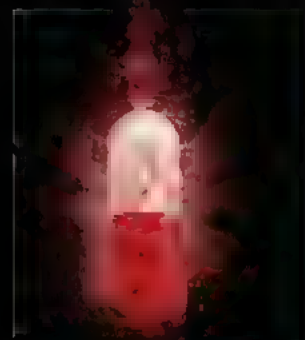


3. LESS INSECTICIDE

On the plus side, if there were no longer any insects, we wouldn't need the 430,000 tonnes of insecticides that are sprayed onto crops every year. In the US, pesticide residues cause between 4,000 and 20,000 cases of cancer each year, according to the National Academy of Sciences. But this is a small compensation for total ecological collapse and global famine.

Can the placebo effect harm you?

AMMAR EL-BEIK, BY EMAIL



Just as the placebo effect causes positive results if you believe you are taking beneficial medicine, there is a negative version, called the nocebo effect. This creates harmful effects such as pain, high blood pressure, dizziness and rashes if you believe that these are possible side effects of the medication you have been given, even though it's a placebo. **W**

How long could you survive on beer alone?

COLIN GRAY, FAST E AR

Beer typically has around 40 calories per 100ml (one pint = 568ml). To get your daily 2,000 calories from beer, you'd need to drink 11 pints every day, which is hardly healthy. But the alcohol is the least of your problems. Beer, even real ale or Guinness, contains no fat, almost no protein and ~~isn't very nutritious~~. Without the support of vitamin C, you'll experience symptoms of scurvy in two or three months and be dead in six. **W**

IN NUMBERS

25

100

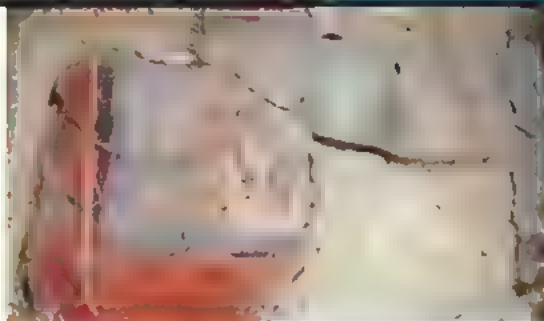
6,000



How hot could Earth get before it's uninhabitable for humans?

JACOB HIPKISS, SOUTHWEL

Humans need to sweat to survive in warm conditions, and that's only possible if the combination of temperature and humidity – known as the wet bulb temperature – stays below around 35°C. According to a 2012 study by scientists at MIT, this limit could be reached globally if our planet warms by around 12°C. Fortunately, few scientists think global warming will do this in the foreseeable future. **W**



What is being done to preserve Pompeii?

SARAH FOX, A S PALA

The main threat to the already excavated buildings and mosaics is moisture, which attacks the plaster and mortar. But Pompeii has attracted the best archaeological conservationists from around the world. In 2012, a 10-year project began installing protective roofs, removing existing moisture and researching the chemical structure of ancient plasters. There is also a moratorium on new archaeological excavations. **W**

PHOTO: GETTY IMAGES/PAUL HARRIS

WHAT HAPPENS IN MY BODY...

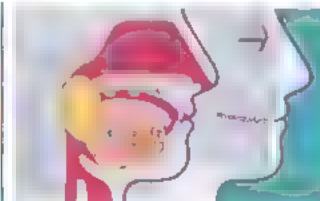
...WHEN I SLEEP?

Sleep consists of two radically different physiological states. There is rapid eye movement sleep (REM) and non-rapid eye movement sleep (NREM). The sleep stage is said to have different functions, but why we sleep is still not completely understood. Babies spend half of their sleep in REM, but this drops to a quarter by the age of two. It is therefore thought that REM sleep is particularly vital for the developing brain. In NREM sleep, brain activity slows and a person woken at this stage may feel groggy.



1 Pituitary gland

During non-REM sleep, the pituitary gland produces growth hormone and secretes prolactin. This counteracts dopamine, to lower general arousal levels.



2 Mouth

You produce less saliva, which reduces the need to swallow. Five per cent of adults also grind their teeth at night, mostly during the early stages of sleep.



3 Lungs

The throat muscles relax so your airway narrows when inhaling. This can cause snoring, or temporarily halt your breathing for a few seconds (sleep apnoea).



4 Heart

Your pulse drops by 10-30bpm while you sleep, lowering your blood pressure. Less blood flows to the brain, and more is diverted to your muscles.



5 Limbs

The extra blood swells your arms and legs slightly. Muscles are paralysed while dreaming, but between dreams you change sleeping position 35 times a night.



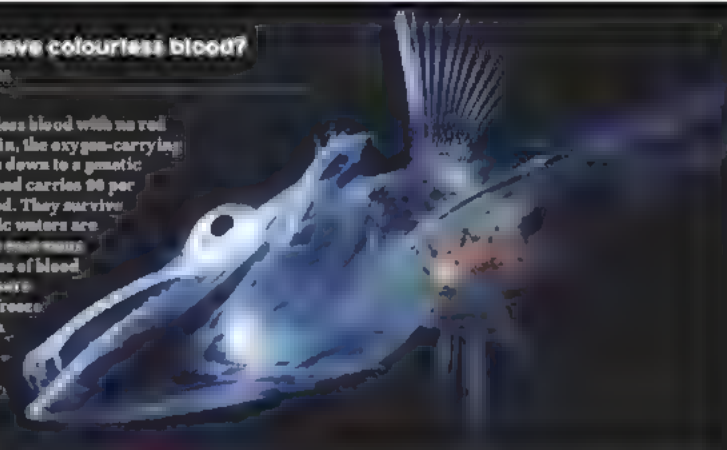
6 Bladder

Vasopressin hormone levels rise. This reduces the amount of urine collected in the bladder to between a half and a third of normal daytime levels.

Why do some fish have colourless blood?

JOSELYN HANSELL, BUCKINGHAMSHIRE

Antarctic icefish have colourless blood with no red blood cells and no haemoglobin, the oxygen-carrying pigment. This probably comes down to a genetic mutation, and means their blood carries 80 per cent less oxygen than red blood. They survive partly because frigid Antarctic waters are oxygen-rich. Icefish also have muscular hearts that pump huge volumes of blood around their bodies, making sure they get enough oxygen. Antifreeze in their blood stops them from freezing (the salty Southern Ocean gets down to -2°C) but as they are so well-adapted to the cold, their future in a warming world remains uncertain. **W**





Does holding your breath make you stronger?

PAD SCANLON, *columnist*

It won't make you stronger in the sense that doing this is a cardio or strength-building exercise. Your breath-holding (or, in certain sports, has been shown to improve the ability of your muscles to cope with short, intense exertions. This works by increasing the concentration of bicarbonate in the blood, which helps to neutralise the lactic acid produced during anaerobic exercise. For this technique to work,

you need to exhale normally and hold your breath when your lungs are empty rather than taking a big breath in and holding that. There are significant risks, though.

A 2009 study found that free divers who regularly hold their breath for several minutes had elevated levels of a protein called S100B in their blood, which is a marker of long-term brain damage. **W**

WHAT'S IN...

...HAND CREAM

There are two ways that hand creams act to moisturise your skin. Occlusive agents form a barrier that traps water, while humectants attract more water to your skin. The problem is that the humectants are water soluble, while the occlusive agents dissolve in oil. So to get them to mix in an easy-to-use formulation, the creams also need an emulsification system. **ML**

WATER 80 per cent

Gives the cream volume and dissolves some ingredients.

GLYCERINE 3 per cent

It's typical humectant used to draw water in from the atmosphere.

THICKENERS 5 per cent

PEG or polyacrylic acid (which may appear as carbomer on the label) are long polymer molecules that increase the viscosity of the cream, making it easier to apply.



FATS AND OILS 7 per cent

Coconut oil, petroleum jelly or lanolin (a waxy substance secreted by woolly animals such as sheep) might be used as occlusive agents that form a barrier to block escaping water.

EMULSIFIER 2.5 per cent

Glyceryl stearate and stearic acid help to stabilise the oil/water mixture.

PRESERVATIVES AND FRAGRANCE 2.5 per cent

These improve the product's shelf life and make it smell nice.

How do stars die?

LESLIE GRIFFIN, *Malvern*

Stars die because they exhaust their nuclear fuel. The events at the end of a star's life depend on its mass. Really massive stars use up their hydrogen fuel quickly but are hot enough to fuse heavier elements such as helium and carbon. Once there is no fuel left, the star collapses and the outer layers explode as a 'supernova'. What's left over after a supernova explosion is a 'neutron star' – the collapsed core of the star – or, if there's sufficient mass, a black hole.

Average-sized stars (up to about 14 times the mass of the Sun) will die less dramatically. As their hydrogen is used up, they swell to become red giants, fusing helium in their cores, before shedding their outer layers, often forming a planetary nebula. The star's core remains as a 'white dwarf', which cools off over billions of years.

The tiniest stars, known as red dwarfs, burn their nuclear fuel so slowly that they might live to be 100 billion years old – much older than the current age of the Universe. **ALC**



If your champagne glasses are grubby, the specks of dirt, betraying your shoddy washing-up skills



Why do champagne bubbles rise from the bottom of a glass?

EWAN HAMISH, *W* *H* *M* *H* *H* *H*

The bubbles are filled with carbon dioxide (CO_2), a gas 800 times less dense than the surrounding liquid. Molecules of this gas accumulating in imperfections in the glass and start to form bubbles. As a low-density supplies enough buoyancy to break off and float towards the surface. In the process they react with the glass, making the bubble even bigger and more buoyant and accelerating its ascent. **RM**

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WHO REALLY DISCOVERED?

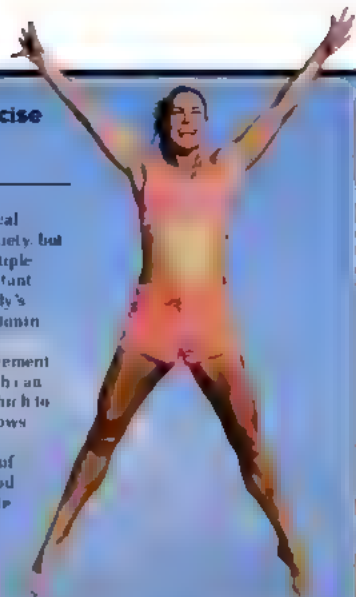


How does physical exercise help reduce stress?

LUCIE COLTMAN VIA TWITTER

Research clearly shows that physical exercise can reduce stress and anxiety, but it's less clear how this occurs. Multiple mechanisms are likely to be important. Exercise can help to reduce the body's response to stress by boosting serotonin levels in the brain.

It can also give us a sense of achievement and increase our self-esteem, which can provide psychological routes by which to reduce stress. Finally, research shows that exercise taken in moderate amounts and at appropriate times of the day can improve our sleep. Good sleep quality can help us to regulate our emotions and therefore provides another way in which physical exercise helps to reduce stress. **ABC**



Do trees reduce air pollution levels?

ROGER LENTON & RORY

The relationship between trees and air pollution is complicated. Particulate matter suspended in polluted air from a car engine, for example, and certain gases including nitrous dioxide (NO₂) are absorbed by leaves. Stomata filtering the air and reducing pollution levels sagally. But trees and other vegetation also restrict airflow in their immediate

vicinity, preventing pollution from being diluted by currents of clean air. In particular, tall trees with thick canopies particulate matter from busy roads can act like a roof, trapping pockets of polluted air at ground level. To relatively improve air quality, city planners need to give careful consideration to how trees are placed. **ABC**

NICHOLAS WATKINS, GETTY IMAGES, SHUTTERSTOCK

WHAT IS THIS?



Filtering perceptions

This creepy-looking robot, called Aibo, was designed by scientists in Japan. The robot is connected up to electronic sensors that detect minute changes in the environment. These differences in temperature, humidity or other elements will influence the robot's movements, which are controlled by a brain-like neural network without any input from humans.



What is the biggest a moon can be in relation to its mother planet?

HOWARD SEYMOUR, HOVE

A 'moon' is an astronomical body that orbits a planet; the definition doesn't involve size. So, a 'moon' could be a small rock or it could be as large as its 'parent'. However, similar-sized objects orbiting each other are normally called 'double' (for example, Pluto-Charon is often considered a 'double dwarf planet').

But the distinction between 'double' and 'parent-moon' systems is not officially defined. Some astronomers define a 'parent-moon' system as one that has the point about which both objects orbit (the barycenter) inside the larger object, but this distinction is quite arbitrary because it depends on both size and separation. **no**



WHAT CONNECTS...

...FROGS AND FRESH MILK?



1.

Frogs, like all amphibians, have thin, porous skin that they can breathe through. But this also poses a risk because it makes it easier for bacteria to infect them.

2.

To protect themselves, frogs secrete substances called cationic antimicrobial peptides (CAMPs). Other animals secrete CAMPs too, but frogs produce much more, including some peptides that are effective against multi-resistant bacteria.



3.

Milk goes off because of bacteria, especially species of *Lactobacilli* and *Pseudomonas*. These ferment the lactose in milk into lactic acid, and hydrolyse milk proteins into various unpleasant-tasting by-products.

4.

According to Russian folklore, putting a live frog in milk would help it stay fresh. Recent research has found that CAMPs from the Russian brown frog could kill the bacteria in milk and prevent it from turning.

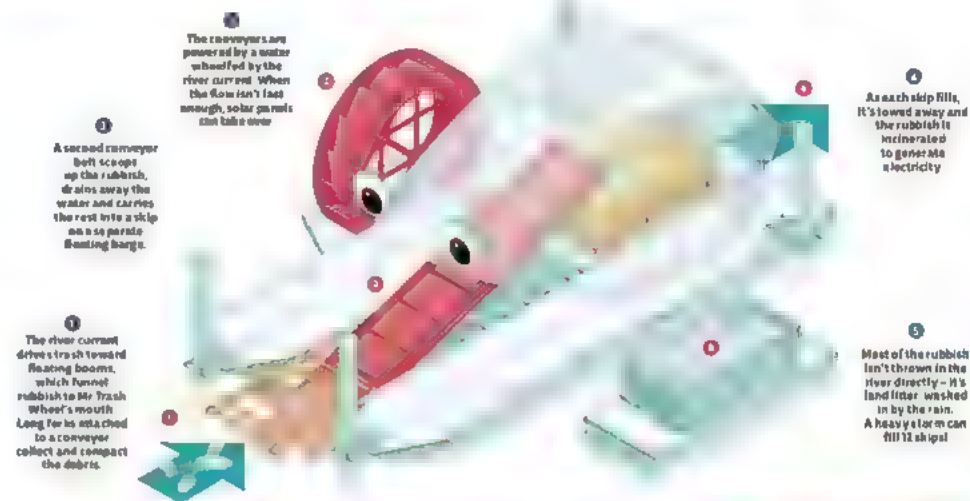


ILLUSTRATIONS: BARRY SAUTTER/GETTY IMAGES; FROGS: ALAMY

HOW IT WORKS

MR TRASH WHEEL

At the mouth of the Jones Falls River, where it feeds into Baltimore Harbour in the US, sits Mr Trash Wheel. Since 2014, this semi-autonomous floating rubbish collector has scooped up more than 500 tonnes of detritus, including 9,000,000 cigarette butts, 492,000 coffee cups and 376,000 crisp packets. Mr Trash Wheel cost \$720,000 (£560,000) to build, and has now been joined by Professor Trash Wheel, a female version in a different part of the harbour.



QUESTION OF THE MONTH

Do all fish and shellfish contain mercury?

JACK FISHING, FRIDAY

Mercury levels in the oceans have tripled since the Industrial Revolution, thanks to mining and the burning of fossil fuels. All sea creatures absorb some of this heavy metal directly, and once it's in the body there's no way of getting rid of it. The amount of mercury in fish varies between species. Long-lived predators like tuna and swordfish tend to contain the most, because they also absorb mercury from their prey and they've had a long time to accumulate it. The lowest levels are found in short-lived species lower down the food chain, such as oysters and shrimp. **no**

WINNER!

Just-Move wins against...
The winner is the Just-Move, a smartwatch with a bright LED neckband, the stylish earphones are designed to make you stand out and be seen, improving safety for runners at night.

WHAT IS IT?

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

ARCTIC

WINTER



CLIMB ABOVE THE CLOUDS

WINTER: LIFE AT THE EXTREMES
BY MICHAEL
SPECTOR

Put on your walking boots and crack out the Kamel Sherpa. A new three-part series from the BBC's Natural History Unit takes us into the heart of three of the most remote mountain ranges on our planet: the Rockies in North America, the Himalayas in Asia and the Andes in South America. *Mountain Life At The Extremes* shines a light on the people and animals that thrive at great heights. In the Rockies, we meet the elusive wolverine, migrating golden eagle, and the elusive, elusive, elusive.

And a dandelion wings. (Her who hangs from the high cliffs, while the spectacular footage of the Himalayas includes India's and Nepal's Valley (pictured here) and Everest itself, where a hardy few take on the world's highest-altitude marathons. Finally, in the Andes, look out for some hardy salt-flat lizards that somehow manage to survive in the world's driest desert. The incredible shape-shifting rainforest, and a Peruvian has journey that ought to come with a change of underwear.

02 EXPERIENCE PSYCHOSIS

HELLBLADE: SENUA'S SACRIFICE
PS4/PC
OUT 8 AUGUST

New video game *Hellblade* follows the story of Senua, a traumatised Celtic warrior whose only quest is to save her lover's soul from the underworld. Senua experiences frequent voice-hearings and hallucinations during her journey, all symptoms of psychosis – a condition that the game's developers at Ninja Theory were keen to portray as accurately as possible.

Hellblade has received funding from the Wellcome Trust, and its creators have been working closely with Prof Paul Fletcher, a neuropsychologist and psychosis expert at the University of Cambridge. We spoke to Fletcher and *Hellblade*'s creative director Tameem Antoniades about how they went about representing mental illness onscreen.

Who is Senua and what is her story?

TA: Senua is a Celtic warrior from the late 8th Century whose Orkney homeland has been invaded by the Vikings. They've sacrificed her lover to the Norse gods and so she

sets off on a quest to Hel, the Viking underworld, to retrieve his soul and lay him to rest. During the game, Senua experiences various voice-hearings and beliefs – saying, for example, what we now call psychosis.

How does Senua's psychosis fit in with her backstory?

PT: To some extent, Senua has always seen the world differently from others, but the idea is that the profound trauma she's experienced has triggered these symptoms. Because of her experiences, Senua has lost touch with the reality of those around her. That's really the formal definition of psychosis. We're all more or less prone to psychosis, depending on how we view and experience the world. Trauma can often act as a trigger.

How did the latest research and thinking around psychosis feed into the game's development?

PT: We wanted to represent symptoms such as voice-hearing

and hallucinations, but also to go below the surface and explore what we know about normal perception. We often tend to think that we have a clear representation of reality, but most of the time our minds are actually making things up, deciding what *should* be there, rather than what *is* there. Psychosis is a kind of confused hallucination. These delusions are deeply embedded in the game: the player becomes sensitive to the visual clues and illusions around them as they progress through the world.

Psychosis used to be thought of as this extreme phenomenon that was completely separate from the normal experience of the world. But we are coming to realise that there's a continuum, instead of us being prone to becoming separate from reality. Hopefully this game will help to demonstrate that.

How did you represent such internal and subjective experiences onscreen?

TA: Throughout her journey, Senua hears her internal chatter as

The portrayal of Senua's psychosis is based on solid science

voices, and so the player hears those too. The voices take on different characters, which are sometimes harsh and brutal, sometimes friendly and helpful. We worked closely with a group of voice-hearers to try and get these sounding as realistic as possible.

Senua experiences flashbacks as visual hallucinations, and there are subtle changes in the game's environment as she moves around, based on people's descriptions of how delusions manifest in real life. So trees might shift position slightly, or you might see a hidden pattern in a shadow, or a reflection. It's these patterns that the player needs to find in order to progress in the game.

What else do you hope to achieve with the game?

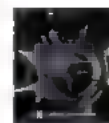
TA: First and foremost, it was about creating a compelling action fantasy game. But the deeper we've gone into development, the more we've seen that there's also an opportunity to raise awareness of psychosis. For my part, I've learnt

that people can experience hallucinations on a day-to-day basis, which is not always a problem – it's a common experience of everyday life. Often the person is not about to harm yourself or hallucinations but finding ways to live with them. That was a revelation for me.

PT: It's been refreshing to see a representation of psychosis in which the person isn't just a sort of passive receptacle for madness. Senua is the hero of her own story, trying to make sense of her experiences and working her way through them – that's an incredibly dignified thing.

In representations of mental illness onscreen, you usually have one-dimensional and then a two-dimensional character attached to that. In this case, the character is fully formed, and they are not defined by their condition. It's been exciting to see Senua receive such positive response from those who have lived with experiences of psychosis.

THREE MORE GAMES OUT THIS MONTH



TATAMA
PC/XBOX ONE
4 AUGUST

Tatama is the latest release from Pol, bright makers of the critically-acclaimed *Gone Home*. *Tatama* is a narrative adventure set in a deserted space station 200,000 miles from Earth. Its crew of six have been stranded in a desperate effort to fix a black box, and it's your job to piece together exactly what happened.



SONIC MANIA
PS4/XBOX ONE/
NINTENDO SWITCH
7 AUGUST

Well, come back. Obnoxious. So much to be angry about in this 2D Sonic-themed game with this outrageous Sonic game engine. There are retro-inspired levels from a game released in the 1990s, as well as a new level called 'Tails and Knuckles'.



UNCHARTED: THE LOST LEGACY
PS4
2 AUGUST

Uncharted 4: A Thief's End was many critics' game of 2016. It's a standard one-expansion, not six months after the main game. It follows new protagonist Chloe Frazer as she explores the southern coast of India in search of a priceless relic. Expect a typically fun and thrilling from developers Naughty Dog.

03 MEET THE QUACKS

QUACKS
BBC TWO, AUGUST
(SEE [RADIOTIMES.COM](http://radiotimes.com)
FOR DETAILS)

You wouldn't want to be treated by this lot. Inspired by real-life Victorian doctors, *Quacks* is a new six-part comedy set in the medical milieu of 1840s London. Created by James Wood, *Quacks* stars Rory Kinnear as a showman surgeon, Mathew Baynton as a fledgling psychiatrist, Tom Basden as a hedonistic dentist, and Lydia Leonard as a social campaigner who's fighting against the medical patriarchy. Ross MacFarlane, one of the show's advisors at the Wellcome Collection, reveals some of the stranger-than-fiction stories that inspired the series...

HUMAN GUINEA PIGS

Doctors in the 1840s were looking for new ways to numb pain. Chloroform was one of the candidate anaesthetics, and in 1847, Scottish physician James Young Simpson and two friends tried it out after a dinner party. The three of them were found passed out – but happily, still alive – on Simpson's drawing room floor the next morning.

SOMETHING FOR THE PAIN?

Potent drugs were easy to get hold of in the 1840s. Laudanum, a tincture of opium that's today rated as a Class A substance, could be bought over the counter for anything from childbirth to a mild cough, while diluted versions were even available for children. Thank goodness for Calpol...

NO SCRUBS

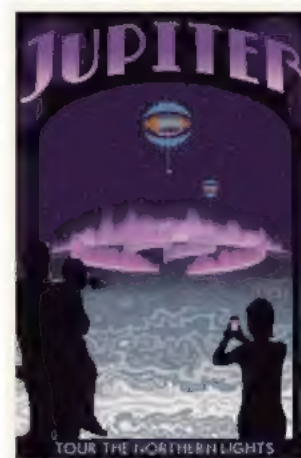
Forget about squeaky-clean surgical clothing: Victorian doctors worked in their finest garb. Think tight dress shirts, cravats and some extravagant hairstyles. They'd at least take their jacket off, though. Scrubs didn't come along until the following century, as scientists became increasingly aware of the link between germs and disease.

LOOK INTO MY EYES

John Elliotson, professor of medicine at University College Hospital, used 'mesmerism' as a form of pain relief. The technique, similar to hypnosis, was derided by many other doctors, notably in an 1842 article accusing him of placing mesmerised female patients in 'curious postures'.



Would you trust this medical bunch to treat you?



04 SOJOURN IN SPACE

THE VACATION GUIDE TO THE SOLAR SYSTEM
BY OLIVIA KOSKI & JANA GREENVICH
OUT 3 AUGUST (£19.99, SQUARE PEG)

You know where we really want to go on our holidays? Outer space, that's where we want to go. Just imagine taking an airship through Venus's lemon-yellow clouds, or enjoying breakfast while looking out onto Saturn's swirling, hexagonal vortex! It's hard to see how Marbella or Lanzarote could possibly compete.

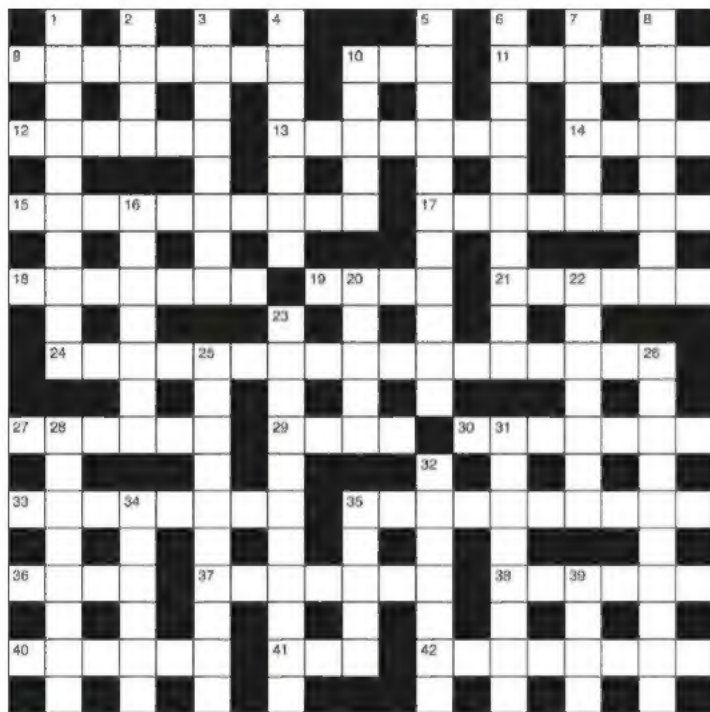
But of course, any budding space tourist will need a guide book. Luckily, *The Vacation Guide To*

The Solar System is packed full of advice on where to go, what to pack, and what to do while you're there. Featuring beautiful retro-inspired illustrations by Steve Thomas, the book's certainly a tongue-in-cheek affair, but the descriptions of the various destinations are all rooted in sound science. With human spaceflight back in the public eye, maybe it's time to swap those shorts and sarongs for a spacesuit.

PHOTOS: BBC, STEVE THOMAS

BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 9 Family cites new science (8)
 10 Broadcasting system becomes a friend (3)
 11 Alternatively, youngster left out a bloomer (6)
 12 Constructing cot, worker made part of a circle (6)
 13 Male feline gets caught in tuba (7)
 14 Flutes surrounding another instrument (4)
 15 Spinning machine created cute fringe (10)
 17 Telling family member (8)
 18 Secrecy of some bombers (7)
 19 Details of his pectorals (4)
 21 Argonaut takes gold home first (6)
 24 Treatment – that takes me back (10,7)
 27 Miniature old basin gets thrown around (6)
 29 Air Force has time for simple vessel (4)

- 30 Everything in gray displayed in exhibition hall (7)
 33 Anglo-Saxon prince hating to work with the Spanish (8)
 35 Group of children have share of genetic material (10)
 36 Old country is different in the morning (4)
 37 Sailor, unaccompanied, finds shell (7)
 38 Percussion instrument reportedly has character (6)
 40 First appeared to have energy round island (6)
 41 Chap takes turn to acquire colour (3)
 42 Igloo yet affecting cause of disease (8)

DOWN

- 1 Gain city a large bottle (10)
 2 Iron, thanks to cheese (4)
 3 Line travelled in London area (8)
 4 Solved this sum to get a bit of land (7)
 5 The excitement of a charged current (10)
 6 Heron flying with combination to find dark amphibole (10)
 7 Old church has a great deal for cat (6)
 8 Endless goodness shown by huge round master (8)
 10 Bean shows sign of life (5)
 16 Used as great crowd disperser (4,3)
 20 Evidence of alcohol (5)
 22 Superficial, swapping end bulb (7)
 23 Hags portray new mapping of the heavens (11)
 25 Menial trio running someone's last race (10)
 26 New boy has a right to give thug a hand (10)
 28 Thor-shaped image in camera tube (8)
 31 Poem that's initially meaningful (8)
 32 A number turn it green (7)
 34 Miner wore European fur (6)
 35 German left awed to the world (5)
 39 Defraud out of a drink (4)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW. Please be aware the website address is case-sensitive.

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"Indiana Jones and I have different policies on artefact acquisition. I try to avoid any sort of death trap"

Archaeologist Brenna Hassett talks to Helen Pilcher about her adventures, and wonders whether cities will be the making – or the death – of us

What do you do?

I dig up dead people and study their teeth and bones so I can work out what their lives were like.

An archaeologist, eh? How like Indiana Jones are you?

Indiana Jones and I have different policies on artefact acquisition. I go with the systematic, planned scientific excavation and generally try to avoid any sort of death trap. The travel and the worrying choice of clothing are, however, accurate. Hats are critical. I cannot stress how important hats are.

Ever found a 'Lost Ark'?

No, but I have found lots of cool stuff. I once found an Aladdin-style, ceramic lamp on a remote Greek island. At the time, I had no idea of its age or origins. I later learned it was a pilgrim's lamp that had been made in the Holy Land during the 6th Century.

Where have you worked?

I've done archaeological surveys in Greece, which involves walking in straight lines for unreasonable amounts of time in unreasonable amounts of heat, starting at the ground looking for artefacts. I worked on the workers who built the pyramids at Giza. I've studied the teeth of children who lived in London 500 years ago, and I've investigated the remains of people who lived in early Turkish settlements 10,000 years ago.

Tell me something clever that you've learned...

We've made major changes to our species in the 15,000 years since humans went from being hunter-gatherers to a settled society. Our rapid evolution into an urban species has affected our bodies and health. Urban living has led to disease and dental decay. Cities created inequality because when you get so many people living together, someone always appoints themselves manager. City life is killing us.

Should we ban cities?

No. Cities create problems but they're also the place where solutions are born. Cities are bastions of progressive thought. I live in a city. I'm 'Team City'.

Has your work ever got you in trouble?

I once did an archaeological survey in Thailand. I was walking through a banana plantation when I got attacked by fire ants. They drop out of the trees, get under your



clothes and start biting. Shortly after that, I learned it's inappropriate to run screaming, taking off your clothes in front of a Buddhist monastery.

So can anyone do archaeology?

That's a great thing about it. Archaeology surfaces any place where land is disturbed. Look in the flowerbeds in St James's Park in London, or anywhere people have lived in the last 300 years, and you're highly likely to find artefacts, like little clay pipe stems. They're the cigarette butts of the early modern era!

Dr Brenna Hassett is an archaeologist. Her book *Built On Bones: 15,000 Years Of Urban Life And Death* (£14.99, Bloomsbury) is out now.

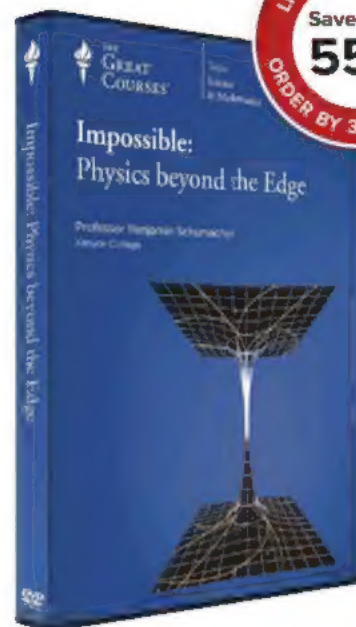
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NEXT ISSUE: EMMA SHERLOCK



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